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Institution

MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. XLI.

SESSION 1874-75.—PART III.

EDITED BY

JAMES FORREST, ASSOC. INST. C.E., SECRETARY.

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ERRATA.

Vol. xl., p. 313, line 8, the name "Furens" has been inserted accidentally.
„ p. 349, line 24 from bottom, for "one-half" read "one-twentieth."

THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1874-75.—PART III.

SECT. I.—MINUTES OF PROCEEDINGS.

February 23, 1875.

THOS. E. HARRISON, President,
in the Chair.

No. 1,419.—"The Working of Railways."[1] By GEORGE FINDLAY, Assoc. Inst. C.E.

THE enormous and continued development of railway traffic during the last twenty-five years has demanded the greatest ingenuity and ability, both of management and of engineering and mechanical skill, to admit of its being conducted with order and regularity. The Author does not propose to deal with that part of the subject relating to signals and the block telegraph, as they are almost universally adopted by railway companies, but rather to explain the arrangements which enable the traffic of the chief lines to be carried on. That traffic consists of express and mail passenger trains, running at an average rate of 40 miles an hour or more, others at a speed of from 34 to 38 miles an hour, and the parliamentary or stopping trains, calling at all stations, and running at a speed of from 19 to 28 miles an hour. Also of express goods trains between all the most important towns, attaining a speed of 20 to 25 miles an hour, of slow or stopping goods trains to supply the necessary service to less important places, followed, in their turn, by heavy coal trains, between the great coal-fields of the country and every large centre of population.

These comprise, briefly, the elements of railway management and

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[1] The discussion upon this Paper was taken in conjunction with that upon the two following ones, and was continued over portions of four evenings, but an abstract of the whole is given consecutively.

working. The fast and the slow trains, the heavy and the light trains, all to be accommodated, or mainly so, on the same lines of rails, representing, when in motion, an enormous weight and momentum to be controlled and regulated, under the varying circumstances of the seasons, in fog and storm, by night and by day. The navigation of the sea, on a difficult and dangerous coast, is not more arduous or dangerous, nor are the seamen exposed to greater risks and hardships than are the railway servants who work the traffic of the country continuously through the depth of winter; and, indeed, the manner in which the service is performed, although not generally understood or appreciated entitles them to high praise.

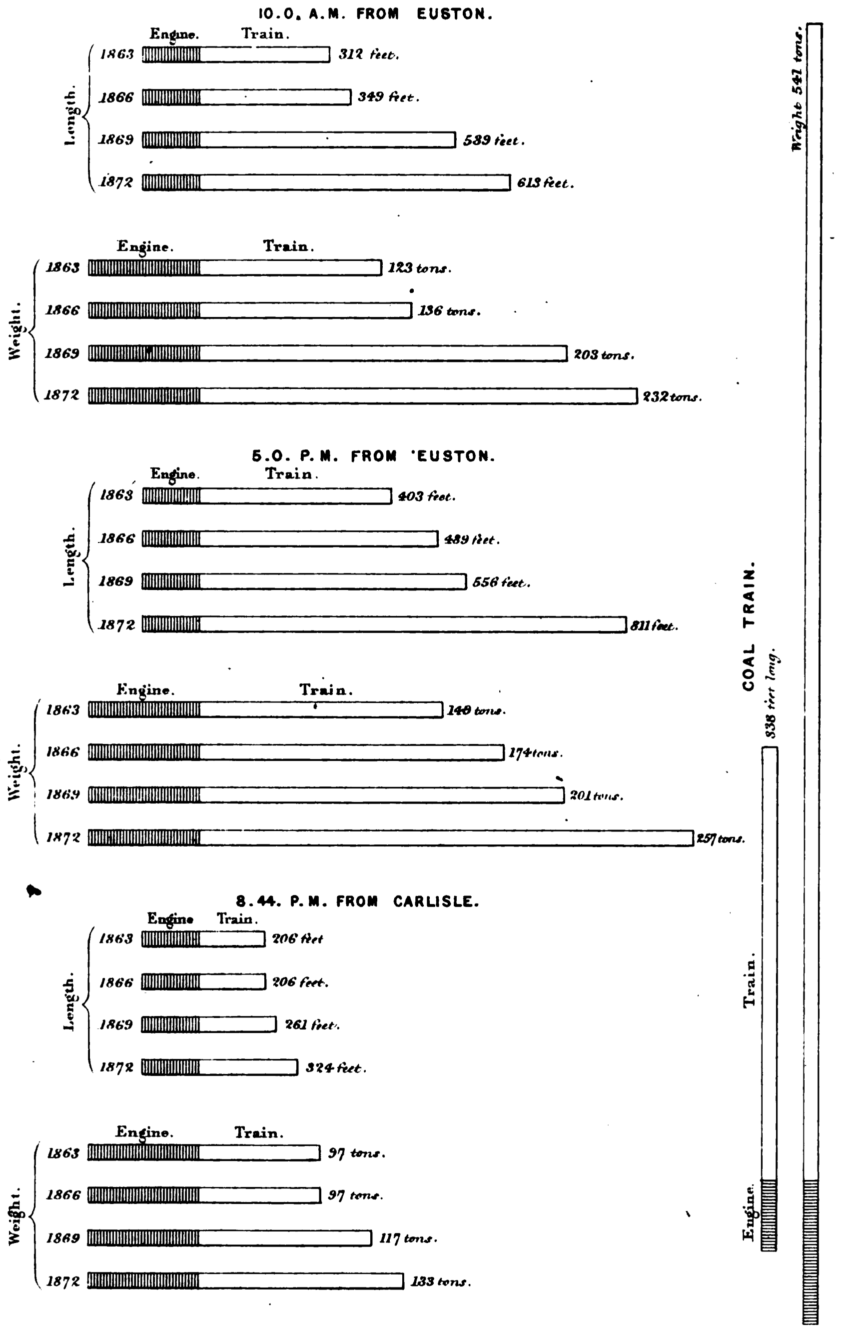
To carry on this great traffic, the essentials are a good permanent way, efficient and powerful engines and rolling stock, proper signalling arrangements, and the speaking and block telegraph, together with a highly trained and thoroughly qualified staff. These are the first great requirements, without which nothing can be done well, and railway companies spare neither trouble nor expense to secure and maintain them.

To illustrate the working of the traffic on the London and North-Western railway, it may be mentioned that, for the purposes of superintendence, the line is separated into several divisions, each of which is under the charge of an officer of practical experience, who is responsible for the train arrangements, and for the order and discipline of the staff. Under him there is an assistant and several travelling inspectors, who regularly visit the stations and signal posts, and make investigations and reports. Encouragement is given to any suggestion having for its object the improved working of the trains and the avoidance of irregularities or delays. The passenger traffic is principally carried on during the day, while, during the night, the more laborious operations of working the goods trains have to be accomplished.

One important element of the subject is the system adopted to insure the maintenance of a thoroughly efficient and well-trained staff. Where the nature of the work will allow, it is the practice to appoint lads, commencing at the age of fourteen years, as junior porters, telegraph boys, and for other similar employments; these lads grow up in the service, and become experienced in railway duties by the time they are adults. Special attention is paid to the training of signalmen, who are usually promoted from the porters or platelayers, and are, in many cases, employed in the first instance as "porter pointsmen" acting as relief men to the regular signalmen, and as platform porters when not so engaged. They are never intrusted with the sole charge of signals until they have re-

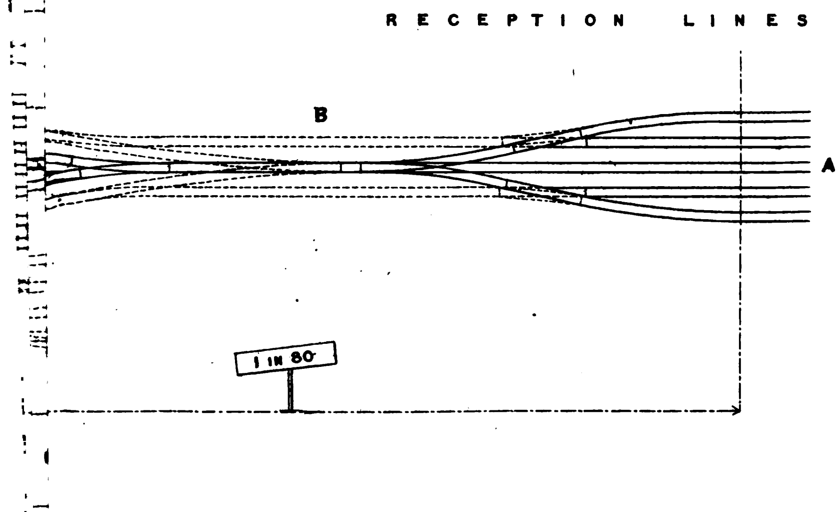
THE WORKING OF RAILWAYS.

COMPARATIVE LENGTH AND WEIGHT OF TRAINS.



Scale: 320 Feet = 1 Inch. 80 Tons = 1 Inch.

PLATE 2.



THOS KELL, LITH. 40, KING ST COVENT GARI

ceived sufficient instruction, the period of training usually varying according to the importance of the post at which they are stationed; nor is their appointment confirmed until the superintendent of the division has certified that, having personally examined the men, he finds them in all respects qualified for the positions they are required to fill. The guards of passenger trains are almost always chosen from the most experienced platform porters, and the breaksmen of goods trains from the goods porters, shunters, and men of that class. They gain their experience by being at first employed to assist the regular guards or breaksmen. They are required to undergo an examination by the superintendent of the district, who certifies that they are duly qualified, and the passenger guards are also examined and approved by the chief passenger superintendent, especial regard being paid to their intelligence and address.

In order to keep up the efficiency of the staff, it is the invariable practice on the London and North-Western railway to select men for promotion to the superior positions of inspectors, foremen, and station masters, and the higher grades of the service, by merit, the best man for the particular duty being taken, irrespective of length of service or any other circumstance. Thus not unfrequently station masters have risen, in consequence of their aptitude, to the rank of divisional superintendents.

Engine-drivers are also carefully trained in their duties before being placed in charge of a locomotive. They ordinarily commence service as lads in the engine sheds in the capacity of cleaners, and after a time are promoted to be drivers of goods trains, and eventually of the slow or local passenger trains; ultimately the most efficient become the drivers of the express passenger trains.

The total number of the staff employed by the London and North-Western Railway Company is about forty thousand, of whom sixteen thousand are engaged in connection with the actual working of the traffic.

The mileage of the London and North-Western Railway Company is	1,406
They own and lease jointly with other companies	221
They run over and work other lines to the extent of	333
Total	1,960
They own—Passenger engines	391
„ Goods ditto	1,544
Total	1,935
„ Carriages	2,722
„ Wagons	39,581

The train mileage for the year ending the 30th of June, 1874, was—Passenger	14,460,568
" Goods and mineral	16,097,954
Total	30,558,522
The number of passengers carried during the same period	42,511,777
Ditto tons of goods, coals, and minerals	24,292,894
	£.
The revenue derived from all sources was—Passenger	3,640,640
" " Goods, &c.	5,127,601
Total	8,768,241

The number of trains running over the southern division of the line, between London and Rugby, in each direction is (exclusive of trains between Euston and Willesden, Watford, and other stations short of Rugby):—

	Down.	Up.
Passenger	22	23
Goods	23	24
Coal and mineral	19 (empties)	16
Totals	64	63

Of these, thirty express and mail trains attain a speed of about 40 miles an hour, five run at about 36 miles an hour, and the remaining passenger trains are ordinary local stopping trains. Of express goods trains there are thirty-two, of ordinary goods trains, twenty-seven, and of stopping, or local, goods and mineral trains, twenty-three.

The time-bill arrangements between Crewe and London, the time and speed of running, and the intersections of the trains at places where the slow trains are ordered to shunt for the faster trains to pass, are illustrated in a diagram.[1] Relief is afforded to the main line by third lines between Nuneaton and Rugby and between Bletchley and London. It should be mentioned that there will be opened in the course of the ensuing season an additional down line between London and Bletchley, and two new lines between Stafford and Crewe.

As an illustration of the growth in the length and weight of the express passenger trains during the last few years, it may be stated that the 10 A.M. down train from Euston, which in 1863 was

[1] This diagram is similar in character to the one of the Great Northern railway (*vide* Minutes of Proceedings Inst. C.E., vol. xxxviii., plate 32), and has not therefore been reproduced.—SEC. INST. C.E.

312 feet in length and 123 tons in weight, had increased in 1872 to 613 feet in length and 232 tons in weight; while the 5 P.M. down express had during the same period increased from 403 feet in length and 149 tons in weight, to 811 feet in length and 257 tons in weight. (Plate 1.) This indicates, in the most forcible manner, the increased requirements of the traffic, in larger and heavier carriages, and more powerful engines; and these, in their turn, have necessitated a better and more substantial permanent way, and the use of steel rails. During the same period it has also been found necessary to duplicate these trains by running others at 10.10 A.M. and 5.10 P.M.

The following are the principal features of the engines engaged in working the traffic:—

Particulars.	1. "Lady of the Lake" Class.	2. "Big Bloomer" Class.	3. 5 feet 6 inches four Wheels coupled Class.	4. 6 feet 6 inches four Wheels coupled (new).	5. Six Wheels coupled. — Coal Train.
Cylinders—					
Diameter . . .	16 ins.	16 ins.	17 ins.	17 ins.	17 ins.
Stroke . . .	24 "	22 "	24 "	24 "	24 "
Diam. of driving whls.	7 ft. 6 ins.	7 ft.	5 ft. 6 ins.	6 ft. 6 ins.	4 ft. 3 ins.
Wheel-base . . .	15 ft. 5 ins.	16 ft. 10 ins.	15 ft. 8 ins.	15 ft. 8 ins.	15 ft. 6 ins.
Heating surface—	Sq. feet.	Sq. feet.	Sq. feet.	Sq. feet.	Sq. feet.
Tubes	981·0	1,062·9	980·0	980·0	980·0
Fire-box . . .	87·3	103·5	94·6	103·5	94·6
Total .	1,068·3	1,166·4	1,074·6	1,083·5	1,074·6
Grate area . . .	15	17·1	17·1	17·1	17·1
Weight—	Tons. cwt.	Tons. cwt.	Tons. cwt.	Tons. cwt.	Tons. cwt.
In working order	27 5	30 16	31 8	32 10	29 11
On driving wheels	11 10 one pair	12 0 one pair.	21 4 two pairs.	22 10 two pairs.	29 11 threepairs.

Although the express trains have hitherto been drawn mostly by single engines, such as those of the "Lady of the Lake" and the "Bloomer" class, it is now deemed expedient to work the heavier express trains by a coupled engine, and for this purpose Mr. Webb, M. Inst. C.E., has constructed several of the type shown in column 4.

The load of goods and mineral trains is as follows:—

	No. of Wagons.	Weight of Trains.
Goods trains	45	292½ tons.
Mineral ditto	35	350 "

The speed of coal trains is limited, as far as practicable, to 15 miles an hour. Mr. Webb has designed for this class of traffic a six-wheeled coupled engine (see column 5 in the preceding table), which has obtained the most favourable results.

Although, by the introduction of the block telegraph, additional break power has been rendered less important than when the traffic was worked on the time system, the company have adopted, for their principal express and suburban trains, a modification of Clark's friction break, suggested by Mr. Webb, which is both powerful and effective. They are, however, of opinion, that so powerful an agent should not be employed for ordinary stoppages, and that, beyond seeing that it is in proper working order, it should only be used in cases of emergency, and subject to the following regulations:—

1. "The lever for working Clark's break is distinct from the van break, and though applied from the van, it does not act upon the wheels of the van itself.
2. "For ordinary stoppages at roadside and terminal stations the van break alone is to be used, except as stated in paragraphs Nos. 4 and 5.
3. "Clark's breaks are not to be put on for such ordinary purposes, or for stopping a train entering a terminal station, but the guards must be on the alert, and apply them at once should the driver give the break whistle, or in the event of the train running past, or being likely to run past a danger signal, or overshooting a platform, or running too fast into a terminus, or in any case when they deem it necessary to pull up the train more quickly than could be done by the van breaks.
4. "In order to ensure Clark's breaks being kept in good order for use on emergencies, and to test their being so, they are always to be applied, instead of the ordinary van break, for stopping the train at the first station at which the train is timed to stop, say Willesden Junction on the down journey.
5. "If at any station the continuity of the chain which connects the break has been interfered with by the separation of the train into sections, or the attaching or detaching of vehicles, the guards are to apply Clark's break at the next station at which the train is timed to stop.
6. "If on any application of the breaks they are found not to be in perfect working order, and the defect cannot immediately be remedied by the guards, they must at once apprize the driver of the fact for his guidance.
7. "In every case of the application of Clark's break, except at the first stopping station, the reason for using it is to be entered in the guards' journals.
8. "The guards are to understand that the application of Clark's break is not to supersede the use of the ordinary break, but that whenever circumstances arise which render it necessary to apply Clark's, the ordinary van break is also to be put on."

Could the theory of the time bill, with regularly appointed

trains, running at different rates of speed, and with specified places and sidings for them to pass each other, be realised in every-day practice, railway working would be perfect; but with various classes of traffic, with express and slow trains, both goods and passenger, and special trains of all descriptions, this can never be absolutely attained. The first requirement is to keep the line free for passenger trains, and, in practice, everything must give way to this necessity. There can be no doubt that it is an object of the greatest importance upon a well-regulated railway to secure the punctuality of the passenger service; nothing adds so much to the character of the line, or to the credit of the officers and men, as a properly appointed and punctual service; it pleases the public who use the line, and is alike creditable and profitable to the company. This is what all companies aim at; it is the object of their daily thought and care; but though the average of unpunctual trains is small, the trains will always be late at certain seasons of the year—as in summer, by largely increased traffic, by the great quantity of luggage conveyed to seaside resorts, the Lakes and Scotland, and by the correspondingly augmented weight of the trains. Again, the people of this country object to submit to the same control as on Continental railways. If it were possible to apply the Continental system, there would be less delay at roadside and junction stations, and greater punctuality. But the ordinary British traveller will travel fast, if possible, and under these circumstances, absolute punctuality is out of the question. In winter the fogs, frosts, and snowstorms affect the progress of trains in connection with the cross-Channel service with Ireland and the Continent. Again trains from the extreme north of Scotland, or from Wales, in connection with a long system of single lines of railway, can never be invariably punctual. The arrangements, therefore, must be such as to enable these trains to be run at irregular times, as well as if the appointed hours were kept. It is obviously to the advantage of the public that this should be so, as it is better to receive the mails from Scotland or Ireland late, than not at all.

The system of telegraphing the progress of trains from one principal station to another, and the regulations for shunting goods trains off the main line, alluded to hereafter, render the running of late passenger trains a matter of certainty and safety.

Goods trains starting from terminal stations, where the shunting and marshalling of wagons take place, cannot always leave punctually; nor can those having work to do at roadside stations, where a margin of time is allowed for the purpose, always ac-

complish it within the prescribed time. The weight of the load, the capacity of the engine, the state of the weather, the gradients, and the frequency of special trains, all interfere so materially with the calculations in compiling the time bill, that the arrangements for shunting goods trains from the main line before the arrival of passenger trains at other than the appointed places, devolve largely on the discretion of the station master and the inspectors. All the management can do, under circumstances like these, is to lay down general principles and rules for the guidance of the staff, viz.:—

"As a general rule, passenger trains are to take precedence of goods, cattle, and coal trains; and such trains must not be started from any station when passenger trains are due. This regulation, however, will be subject to modification, according to the circumstances of the trains, the state of the weather, the weight of the load, and the class of the engine:—Thus, a light through goods or cattle train, on a clear day or night, may be started before a passenger train, should the latter have to stop at all the stations. Again, if from facts which may come to the knowledge of the station master, or foreman on duty, by means of the electric telegraph or otherwise, the passenger train which is due may not be expected for some time, they will be justified in despatching the goods train, taking care in this case especially to warn the enginemen of the passenger train when it arrives, the precise time when the goods train was despatched, and where ordered to shunt.

"The same principle will apply to the regulation of slow or stopping passenger trains, when express trains which are timed to follow them are known to be out of course.

"Passenger, goods, mineral, cattle or ballast trains, when appointed in the time tables to shunt for following trains on those portions of the line where the permissive block or the time system is in operation; or when, from slow travelling or other circumstances, they are likely to be overtaken by a following train, must be shunted at stations or sidings at least ten minutes before such following train is expected, and kept there until after it has passed, and the proper signals have been given by the signalman in charge of the siding or station for the train to follow.

"In order to carry out the above rule, the stopping trains therein referred to must not be started from any station or siding where they can shunt, unless there is a sufficient interval to admit of their reaching the next shunting station or siding in time to be shunted ten minutes clear of the following train in the terms of the above rule.

"Where the absolute block system is in operation, the train must be shunted clear of the main line before 'line clear' is given to the block station in the rear, and the main line must be clear five minutes before the following train is expected."

These are the general rules; but, to admit of a proper discretion being exercised, it has been found desirable to fix absolutely the margin of time within which a goods train may leave a particular station in advance of a passenger train. This information is given in the working book, as well as the locality of shunting sidings, and the number of wagons that each siding will contain, as shown

in the following Table relating to the southern division of the London and North-Western railway:—

List of Shunting Sidings (Southern Division) and Intervals to be observed in despatching Goods and Mineral Trains in advance of Fast Passenger Trains to and from such sidings.

DOWN.

Distance from Camden.	Stations.	Siding capable of holding	Willesden.	Harrow.	Watford.	Boxmoor.	Tring.	Leighton.	Bletchley.	Wolverton.	Roade.	Blisworth.	Heyford.	Weedon.	South end of Kilsby Tunnel.	Hillmorton.	Rugby.
		Wgns.	Min.	Min.	Min.	Min.	Min.	Min.	Min.	Min.	Min.	Min.	Min.	Min.	Min.	Min.	Min.
	Camden . .	..	20	30	45	50	60	65	80	90	..	..	..	..	..	..	..
	Do., 4th Line	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4¼	Willesden Jn.	165	..	25	35	45	55	60	70	80	..	..	..	..	..	..	..
10¼	Harrow . .	65	..	..	25	35	45	55	65	75	..	..	..	..	..	..	..
16¼	Watford . .	50	..	..	..	25	35	45	55	65	..	..	..	..	..	..	..
23	Boxmoor. .	80	..	..	..	..	25	25	45	55	..	..	..	..	..	..	..
30½	Tring . .	50	..	..	..	..	..	30	40	50	60	65	70	75	..	..	95
39¼	Leighton. .	80	..	..	..	..	..	..	25	33	45	50	55	60	..	..	80
45⅛	Bletchley .	65	..	..	..	..	..	..	..	20	30	35	40	45	..	..	65
51	Wolverton .	95	..	..	..	..	..	..	..	..	25	30	35	40	..	..	60
58¾	Roade . .	50	..	..	..	..	..	..	..	..	..	20	30	35	45	50	55
61¾	Blisworth .	50	..	..	..	..	..	..	..	..	..	..	20	30	40	45	50
66	Heyford . .	95	..	..	..	..	..	..	..	..	..	..	..	20	35	40	40
68¼	Weedon . .	85	..	..	..	..	..	..	..	..	..	..	..	..	30	35	40
75	S. of Kilsby Tunnel	100	..	..	..	..	..	..	..	..	..	..	..	..	..	25	30
79⅛	Hillmorton .	145	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20

Similar arrangements exist with regard to the up trains.

This, however, is not all. To insure the principal station masters and inspectors being kept well informed of the working of the line and the running of the passenger and goods trains, a system of telegraphing their progress from station to station is organised, which is illustrated by the following divisional instructions in force between Stafford and Crewe. (See next page.)

With this information, the signalman has a discretion in arranging the shunting of slow trains for fast ones to pass, which is provided for on the block system by the signalman giving seven strokes on the bell to the station in advance.

To distinguish fast and slow passenger or goods trains on the journey, the following arrangement of head lights has been adopted:—

"Engines of fast passenger trains, and breakdown van trains—two white lights, one over each buffer.

"Engines of slow passenger trains, and light engines—a white light over left-hand buffer.

"Engines of express goods or cattle trains—two green lights, one over each buffer.

"Engines of stopping goods, mineral, or ballast trains—one green light over left-hand buffer.

"Trains or engines when travelling on third or fourth lines (*i.e.*, the additional lines constructed for the goods and slow passenger trains) also carry a green light at the foot of the chimney.

"During the day engines attached to express goods or cattle trains carry a white diamond board at the foot of the chimney.

"London and North-Western engines when running over foreign companies' lines also carry the distinctive signals for the line over which they are travelling as laid down in the working time book."

Divisional Instructions in Force between Stafford and Crewe.

From	Train Departures, &c., to be Telegraphed to					
	Stafford. (Station.)	Stafford. (South Box.)	Norton Bridge.	Whitmore.	Crewe. (Shrewsbury Junction.)	Crewe. (Station.)
Stafford (Station)	.. ..	Up Passenger and Goods between 9.0 p.m. and 7.0 a.m. (transmit).	Down Passenger. (Transmit Tamworth and Wolverhampton times.) Down Express Goods.	Down Passenger. (Transmit Tamworth and Wolverhampton times.) Down Express Goods.	Down Passenger and Express Goods.	Down Passenger and Express Goods.
Norton Bridge	.. ..	.. ..	.. ..	Arrivals and departures of Down Express Goods when shunted.	Arrivals and departures of Down Express Goods when shunted.	Arrivals and departures of Down Express Goods when shunted.
Whitmore	Arrivals and departures of Up Express Goods when shunted.	.. ..	.. ..	.. ..	Arrivals and departures of Down Express Goods when shunted.	Arrivals and departures of Down Express Goods when shunted.
Crewe (Shrewsbury Junction)	Up Express Goods.	.. ..	Up Express Goods.	Up Express Goods.	.. ..	.. ..
Crewe (Station)	Up Passenger.	.. ..	Up Passenger.	Up Passenger; Transmit Warrington and Runcorn times and Chester times of Irish Mails.	Up Passenger and Goods (transmit).	.. ..

An additional red board or flag by day, and an extra red light at night or in foggy weather, is hung at the back of an engine or train, to show that a special train is to follow; and in order to indicate whether the special is a passenger or goods

train, the following arrangement of the lamps and boards is observed:—

For a special goods or cattle train, the two lamps at night are arranged thus	O O
For a special passenger train they are arranged thus	O O

By day the red board is placed in a corresponding position with regard to the tail lamp, as that occupied by the extra lamp at night.

These arrangements work well in practice, and are easily carried out by a thoroughly organised and disciplined staff. But such is the growth of the traffic, and the requirements of the Government as to the conveyance of the mails at a high rate of speed during the night, when the line is occupied by the goods traffic, as well as of the public in the competition of service maintained by the greater companies, that the time may arrive when even these arrangements may be inadequate, and when the doubling or duplication of some of the important lines must follow—a plan already adopted through busy districts, and which will still further be considered and extended.

It is only during the passage of the royal train to convey Her Majesty and suite between Windsor and Ballater, that the ordinary arrangements for working the line are suspended. The exceptional nature of the regulations then adopted must be considered as affording the nearest approach to perfection in railway travelling that has yet been arrived at. The train is fitted throughout with continuous breaks, with an electrical communication between the compartments of each saloon and carriage and the guards, and with a communication between the guards and the driver. A pilot engine is run fifteen minutes in advance of the train throughout the entire journey. In order to guard against any obstruction or interference with the safe passage of the train, no engine (except the pilot), or any train or vehicle, is allowed to proceed upon or cross the main line and stations during an interval of at least thirty minutes before the time at which the royal train is appointed to pass. All shunting operations on the adjoining lines are suspended during the same period. While, after the royal train has passed, no engine or train is permitted to leave a station or siding upon the same line for at least fifteen minutes. In addition to these regulations, no light engines or trains, except passenger trains, are allowed to travel between any two stations on the opposite line of rails to that on which the royal train is running, from the time the pilot is due, until the royal train has passed. The precaution is also taken of

specially guarding every level crossing, farm crossing, and station, to prevent trespassers; and of securely bolting all facing points over which the pilot and royal train have to travel. Platelayers are likewise posted along the line to prevent the possibility of any impediment at the occupation road-crossings. Special arrangements are made for telegraphing the passage of the train from point to point, as it speeds along its journey, and an instrument is conveyed by the royal train by means of which a telegraphic communication can be established at any place on the journey in case of need. The train is accompanied by a sufficient number of fitters, lampmen, and greasers, who keep a constant watch on each side of the train, so as to notice any irregularity in the running of the carriages; and who, upon the train stopping at the appointed stations, examine it throughout and grease the axle-boxes. The average speed of the train is 36 miles an hour excluding stoppages.

In working a line like the London and North-Western, the goods trains run with full loads between the most important places. The traffic, at the intermediate stations, is collected by a service of local trains, and conveyed to centres such as Rugby, Crewe, and other junctions, there to be properly marshalled and classified, and from thence to be forwarded by the through trains without further delay.

The duty of marshalling and classifying the goods and mineral traffic into district and station order is a work of enormous magnitude. The business at the terminal stations, such as London, Birmingham, Liverpool, Manchester, and Carlisle, is both complicated and costly. Without this arrangement of trains for their several destinations, and of the wagons in these trains in station order, it would be almost impossible to carry on the goods and mineral traffic without the most serious interruptions and delay. As it is, any neglect or omission on the part of the staff, in this respect, results in unavoidable confusion at the junctions and stations on the journey. The magnitude of these operations may be realised from the fact, that the London and North-Western Railway Company have one hundred and seventy-one engines constantly employed in marshalling and classifying the trains in the sidings, and that the total number of hours of shunting performed last year was 613,472 by the above regular and extra shunting engines, representing a cost to the company, at 5*s.* an hour, of £153,368.

The importance of this work being effectually performed has been fully recognised, and constant attention has been given to secure it, so as to avoid delay and irregularity on the main line,

At terminal stations various methods have been suggested, such as at Camden, where a double line of turntables across the shunting lines is worked by hydraulic capstans, and at other places where there are fan-shaped sidings, each siding holding wagons for different districts, but involving a separate operation to place them in station order. At other places the sidings have been arranged on a similar plan, but with the gradient falling with the load so as to economise power; but it has remained for Mr. Harry Footner, M. Inst. C.E., an officer of the London and North-Western Company, to devise, in 1873, a plan by which the wagons can be marshalled in district and station order at the same time. This plan has been ordered to be carried out at Edgehill (Liverpool) in the first instance. (Plate 2.) It is described by Mr. Footner as follows:—

"All Liverpool traffic arrives at, or is despatched from Edgehill. Inward trains are here broken up and the wagons forwarded to the goods stations and depôts on the line of docks. Edgehill is a store from which full or empty trucks can be had when required for the supply of the depôts, or to which wagons can be sent from the depôts as soon as loaded or unloaded. Besides the goods stations, there are cattle stations, agricultural and coal yards, wagon-repairing shops, sheeting sheds, locomotive coal stages, permanent-way workshops, &c., to be regularly supplied. More than three hundred trains enter and leave the station daily, Sundays excepted. As the flow of traffic to and from the goods stations is steadily continuous during the day, and generally ceases during the night; while, on the other hand, the trains arrive and depart at irregular hours, and principally at night, there is a period in the afternoon at Edgehill when standing room for an accumulation of wagons is required, in addition to the sidings upon which the shunting engines are at work.

"Owing to successive additions to meet the increased traffic, the arrangement of the station, at one time simple and suitable for the demands then made upon it, has now become inconvenient and expensive. The passenger main lines pass through the centre, the sidings are irregularly grouped, and there are no independent main goods lines on which trains may be stopped before entering the station, or on which trains ready to start may proceed to relieve the yard without obstructing the passenger lines.

"The company possesses 30 or 40 acres of land adjoining the station, the surface of which (5 feet at one end, and 35 feet at the other above the rail-level) suggested an arrangement of sidings for sorting and marshalling the trains chiefly by gravitation. It was thought that if all necessary changes could be made by once

passing the wagons down the incline, the plan would prove economical, besides possessing other advantages. It was, therefore, proposed that sorting the trucks into trains, and arranging the trucks in each train in their proper order should be distinct operations; and that independent lines, up and down, should be laid, over which the short trains or sets of wagons that come from the depôts might be brought directly to some (reception) lines at the top of the incline; the receiving lines to communicate at their lower end with a number of sidings (standing lines), into which the wagons would at once be sorted; each of these standing lines to represent a district or particular train between certain hours, and that here the trucks should accumulate until near the hour of the train's departure, when they would be passed through a set of marshalling sidings to put them in their proper order.

"The marshalling sidings, or 'gridirons,' as they are termed, are two sets of seven sidings, arranged as shown on the diagram C D E (Plate 2). They are spaced far enough apart for a horse to work between them, and each siding will hold ten trucks.[1]

"The number of sidings in each gridiron, and the least number of trucks that each siding should contain, is the square root of the number of vehicles in the longest train to be marshalled; but, practically, a larger number than forty-nine can be marshalled in the seven sidings, while the extra length is also required to allow for occasional want of precision in stopping the trucks at the right spot, and to render the method of working them elastic enough to meet special cases.

"The numbers from F to E represent a train of trucks which has passed through the gridirons, and is ready to start on its journey. The numbers from B to C represent the same trucks 'in the rough' in one of the 'factorial N' ways in which they might possibly have arrived there. The train is arbitrarily regarded as being composed of seven sections, and a distinctive shading is given to the trucks in each section, that their course may be readily followed. The first step consists in running the wagons one by one into the upper gridiron C to D, one siding being assigned to each section; the second step is to arrange the wagons in each section in turn, beginning with the first. Let each siding in the lower gridiron receive one of the black trucks; manifestly, in whatever order they arrived in the first gridiron, they can now be started in any desired order from the second. Similarly the remaining sections are dealt with.

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[1] The gradients of the 'gridirons' are from 1 in 80 to 1 in 90, and of the 'standing' lines from 1 in 90 to 1 in 120.

"It is well known that an experienced shunter can fix in his memory the destination of every wagon in a train by once reading over the labels upon them. He will, therefore, have no difficulty in dividing them into sections for the first step in the marshalling process. A pair of marshalling gridirons is now being laid down at Edgehill.

"Nowhere on the North-Western system is greater need felt of facilities in arranging trains than at Crewe, where lines from six different directions converge; and plans are prepared for an entirely new station on 80 acres of land, to be worked on the system just described.

"Sorting by gravitation, with or without the assistance of an engine or horses, is successfully carried out at many places. The earliest, and perhaps the most notable, instance on moderate gradients, are the coal sidings leading to the Jarrow Dock Tips, which have been fully described by Mr. Harrison, President Inst. C.E., in a Paper read before this Institution.[1] The steep gradients (1 in 50) at Accrington, on the Lancashire and Yorkshire railway, afford perhaps one of the most remarkable instances of successful working for more than twenty years. Mr. Footner is not aware of any previous attempts to marshal trains in a similar manner."

It is not within the scope of this Paper to do more than allude to the working of the goods traffic at the stations, and to the application of steam and hydraulic power to the cranes, lifts, and arrangements requisite to secure a quick and economical conduct of the business.

All railway companies are now common carriers. Originally this business was conducted over the various railways by the old canal and road carriers. In a few years, however, it became evident that, in order to enable the railway companies to cope with the increasing demands of the public, it should be managed wholly by themselves, the carriers being appointed as the cartage agents in the principal towns. This was a radical change, and contrary to the intention of the original promoters of railways. But, while the result has been of great advantage to the community, some persons think the companies would have benefited to a greater extent had they continued as tolltakers instead of becoming carriers. However this may be, the organisation and method with which this great trade is conducted by all the companies are indeed surprising. The staff of men and horses engaged in the

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 490.

collection and delivery of goods in London, by the London and North-Western Company alone, exceeds the number that was necessary to work all the coaches and carriers' vans that ran in the old days to and from the North. They have, altogether, sixteen hundred men and one thousand horses engaged in the goods business in London. The speed with which this is carried on is remarkable. The collection, transit, and delivery of goods between all the important towns in England is accomplished within the day of twenty-four hours; and between England and Scotland and the ports of Ireland within two days, or forty-eight hours. For corresponding services in France the following statement shows the time allowed by law, and nothing can more forcibly illustrate the pace at which business is managed in this country than such a comparison :—

For goods in classes 1 and 2 (4th and 5th classes of English railway clearing-house classification) the French companies are allowed one day of twenty-four hours for each 124 miles or fraction thereof on the main line.

For goods in other classes on the main line, and also for first and second class on branch lines, twenty-four hours for the first 93 miles, and twenty-four hours for each additional 78 miles.

The companies have one clear day for loading, &c.; and the day on which they receive the goods and that on which they deliver them are not reckoned.

One day extra is allowed at junctions with other companies.

Thus, goods received by a company in London on the 1st of the month would, according to the French system, be delivered in the country as shown in the following table :—

At	Miles.	Classes 1 and 2 on Main Line.	Classes other than 1 and 2 on Main Line, and all Classes on Branch Lines.
		Due on	Due on
Northampton .	66	4th	4th
Birmingham .	111	4th	5th
Liverpool . .	200	5th	6th
Manchester .	182	5th	6th
Dublin . . .	333	6th	8th
Glasgow . .	399	8th	9th

In the case of certain exceptional low rates, the companies are entitled to three, and even five days extra.

The Yorkshire merchant attends the London wool sales; he makes his purchases one day, and the wool is in his warehouse the next. The Lancashire spinner attends the Liverpool cotton market, and expects his cotton delivered, and probably in actual consumption, the next day. The dead meat from Scotland, the poultry, butter and eggs from Ireland, are all despatched with the narrowest margin of time to meet particular markets; and all is accomplished with certainty.

This could only have been done by means of the universal system of through rates and through booking that exists between the companies, and which has been encouraged and developed by the facilities afforded by the railway clearing-houses in England and Ireland, for the settlement of the complicated through-traffic arrangements relating both to goods and rolling stock. Too much cannot be said in praise of an institution which has accomplished so much practical benefit. It is alike creditable to the companies that, whatever their political differences, they meet there on neutral ground, and give each other the benefit of their experience in devising and carrying out regulations regarding through traffic for the general good of all. These arrangements have brought the produce of France, the Channel Islands, and of Ireland within the command of the English markets; and it is not too much to say that, in the case of Ireland, the facilities thus afforded for the transit of cattle, poultry, butter and eggs, and every other marketable commodity, have done much to improve the social condition of the people.

"The harvest of the sea" is an important item in railway traffic. From the day when the first salmon is caught, or the first haul of mackerel is taken off the old Head of Kinsale in the spring, until the close of the Yarmouth fishing towards the end of the year, tens of thousands of tons of fish are conveyed from Milford, Holyhead, Liverpool, Scotland, and the east coast, to London and all the important towns of the kingdom, in excellent condition, and (which was never the case before) at a price within the means of all.

The misfortunes that occur in the conduct of the railway traffic of the country are, from their very nature, serious and alarming to the public. It is not within the province of this Paper to do more (having already pointed out the difficulties of management) than allude to them. When they do happen, none feel the consequences more keenly than those most intimately connected with

railways; and the public are far from realising the ever-increasing care and anxiety of the executive, the ceaseless watchfulness and activity of the staff, necessary to carry on so wonderful a traffic as that of this great country; a business which knows no rest, but is ever in motion, and upon which the health and wealth of the community is largely dependent.

The communication is accompanied by a series of diagrams, from which Plates 1 and 2 have been compiled.

No. 1,406.—"On Sorting Railway Trains by Gravitation."[1] By WILLIAM CUDWORTH, M. Inst. C.E.

THE growth of the railway system, and the multiplication of branch and intersecting lines in a mining and manufacturing country like Great Britain, have brought into prominence among railway managers the question of the proper marshalling of mineral and goods trains.

As a contribution towards the elucidation of the subject, it is proposed to describe what has been done in the construction of sorting sidings on the Darlington section of the North-Eastern railway. This section has a large mineral traffic, and consists of an assemblage of branch lines, upon which the work of collection and distribution is of an intricate character.

A description will first be given of the sorting sidings at Shildon, where (the rails happening to have a convenient inclination) the movement of the trucks during sorting is effected in an inexpensive and expeditious manner by gravitation. The amount of traffic, the number of men employed, the cost of sorting, and some other particulars will be stated. Reference will then be made to the points wherein the arrangement at Shildon has been found defective, and to the way in which it is proposed to remedy these defects; and, lastly, attention will be directed to a large group of sorting sidings in course of construction at Newport, near Middlesborough, in the designing of which the experience gained at Shildon has been brought to bear.

The sidings are a little to the eastward of Shildon, about 8 miles north-west of Darlington, on the old Stockton and Darlington railway. They occupy the first convenient site after the meeting of the lines of railway which, traversing the western part of the county of Durham, bring from that quarter coal, coke, and limestone; and they are upon the south-eastern margin of the coal-field.

The coke and limestone are extensively consumed in the iron furnaces of Cleveland, and there is a large demand for the coal and coke for general manufacturing and household purposes in

[1] The discussion upon this Paper was taken in conjunction with the preceding and the following ones, and was continued over portions of four evenings, but an abstract of the whole is given consecutively.

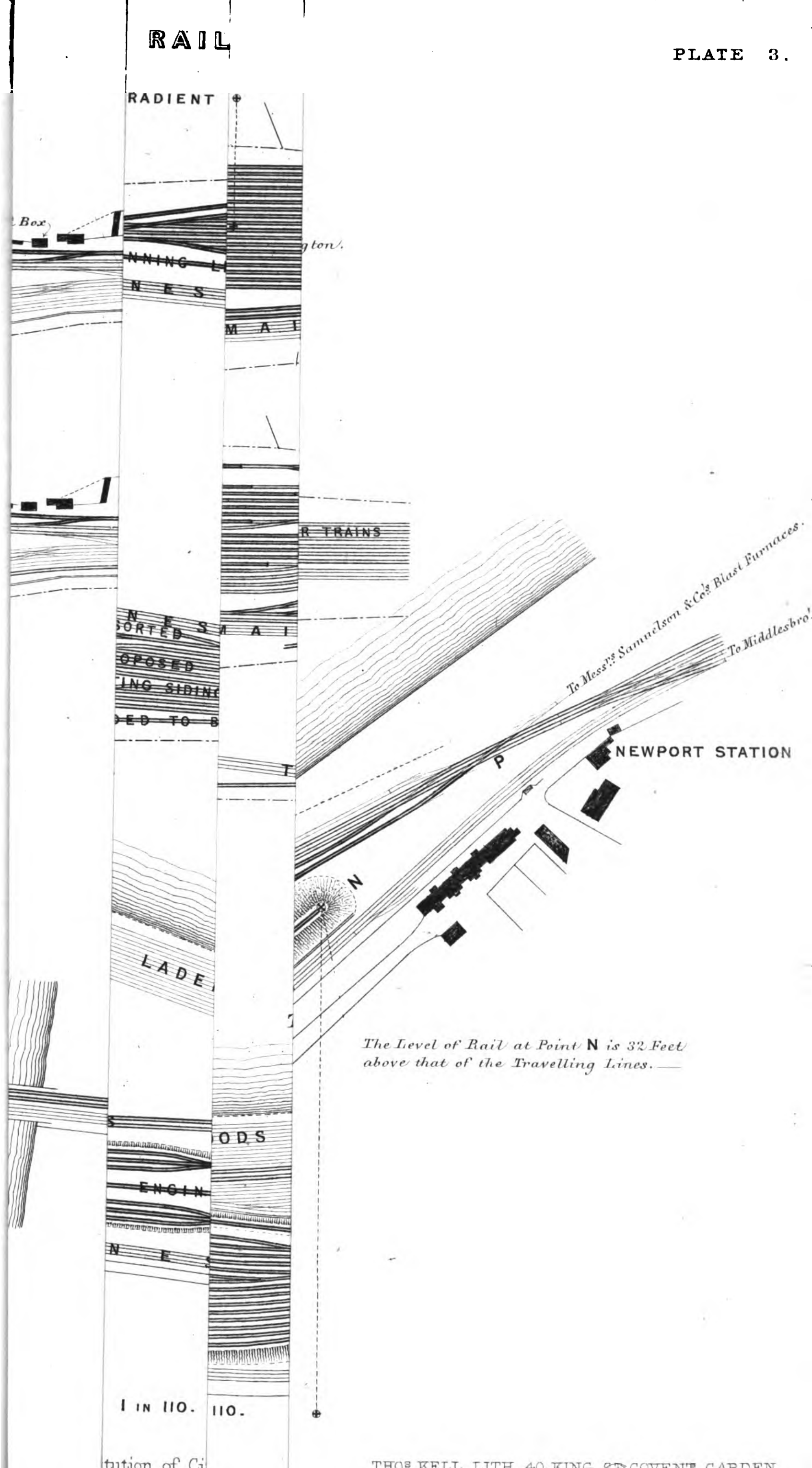
a wide district comprising South Durham, Yorkshire, Lancashire, Lincolnshire, many parts of the Midland Counties, and, to some extent, in London. Shipments coastwise and foreign are also made in the ports of West Hartlepool and Middlesborough. Nearly all this traffic is collected, sorted, and made up into trains in the Shildon sidings; but, on account of their inconvenience, they are not used for the sorting of a further large quantity of coke and some coal, the produce of the same coal-field, which is sent westward to the furnaces at Barrow, Carnforth, Workington, and to other places chiefly on the coast.

The mineral traffic which went through the Shildon sidings in the year 1873 amounted to about 4,760,000 tons. This was derived from about one hundred and twenty different collieries and quarries, and was ticketed to upwards of two hundred different points of delivery.

The necessity for sorting had been felt from the early days of the railway, and a group of sidings, without much preconceived plan, had consequently been laid down by degrees, as occasion required, upon the site of the present sidings, the gradient of the railway favouring the movement of the wagons by gravitation.

About the year 1865, however, the rapid increase of the traffic led Mr. Harrison, President Inst. C.E., the Engineer-in-Chief to the North-Eastern Railway Company, to reconsider the arrangement, with a view to include the old sidings in a comprehensive plan adequate to the wants of the period. The groups of sidings about to be described were accordingly designed, and, after considerable delay in obtaining additional land, for purchasing which it was found needful to obtain Parliamentary power, were carried out by the Author as Engineer on the Darlington section, and completed about four years after the date mentioned.

The *modus operandi* in passing a train through the sidings is as follows:—Upon its arrival from the colliery district, it is first turned into the long siding (A, Plate 3, Fig. 1), where it may stand clear of the main line should there be any accidental obstruction in the group of sidings B, four in number, into one of which, the way being clear, it at once proceeds. The engine is then detached, and is either passed out through the exit line R, or proceeds through the running line S to the end of the groups of sidings C and D, and takes a train forward. The 'shunters,' or sorters, immediately set to work to break up the train so left, and run the trucks in 'sets' of two or three, or half a dozen together, into the various sidings of groups C and D, according to their destination, the rails being so arranged that trucks in any one



THOS. KELL, LITH. 40, KING ST COVENT GARDEN

of the four sidings in group B can run into any one of the thirty-nine sidings in groups C and D. A 'shunter' accompanies each set of trucks, riding upon one of them, but jumping off and running in advance to move any points which may not be standing open for the siding aimed at, in which he ultimately brings the trucks to a stand by the break.

In this manner complete trains are marshalled in the thirty-nine sidings of groups C and D, whence they are forwarded to their various destinations as rapidly as they accumulate. In an average day's work of twenty-four hours about two thousand trucks and wagons are sorted and despatched. With a view to exhibit more clearly the capabilities of the sidings, Mr. William Bouch, Locomotive Engineer on the Darlington section, under whose superintendence the traffic is worked, has prepared a detailed statement of the work done in one day, divided into periods of two hours each. From this it appears that from 6 A.M. December 9, to 6 A.M. December 10, 1873, the number of trucks sorted was two thousand two hundred and fifty-four, and of chaldron wagons seven hundred and thirty; together, two thousand nine hundred and eighty-four vehicles, received in ninety-four trains. The number of shunts corresponding with the number of parts into which the trains were separated was six hundred and ninety-one, averaging four and a third trucks or wagons in each. During the busiest part of the day, from 2 P.M. to 4 P.M., five hundred and seventy-five trucks and one hundred and ninety-six wagons, together seven hundred and seventy-one vehicles, were sorted, after being separated into one hundred and twenty-eight parts or 'sets,' averaging six trucks or wagons in each. In the same twenty-four hours sixty-three engines passed through the engine-running line, to take trains forward out of sidings C and D, and four mineral trains went through which did not require sorting.

The aggregate length of single line in these sidings is :—

	Yards.
In engine-running lines	4,498
In B group of sidings	1,723
In C and D „ „	11,770
In cross-over roads	707
Total	18,698

or upwards of 10½ miles; and they cover about 16 acres of land.

Though the trucks, upon the whole, run freely by gravitation, there are bad runners as well as good runners; the former being most frequently found amongst those called 'foreign trucks,' owned

chiefly by private parties, and amounting to about $\frac{1}{6}$th of the gross number. The superiority of the North-Eastern Company's trucks in this respect is attributed in some measure to the axles being lubricated with oil, besides having the usual supply of grease, the axle boxes being constructed so as not to embrace the lower half of the axle, but to leave it free for lubrication. There are also occasional retarding causes affecting the whole of the trucks and wagons, particularly frosty weather and high contrary winds. For these reasons two shunting engines are kept to assist in the sorting; and when on special occasions they are unequal to the work they are aided by the train engines.

Simultaneously with the sorting of each train, the trucks in it undergo an examination; and if any of them are unfit to travel, they are run into a siding set apart for damaged trucks, whence they are taken to the shops for repairs.

There are employed upon the above sidings thirty-seven sorters and examiners, ten wagon-greasers, and seven inspectors and time-keepers for about half their time; also two locomotive engines. The annual cost is as follows:—

	£.	s.	d.
Inspectors and timekeepers	281	0	4
Sorters and examiners	2,392	8	8
Wagon-greasers	452	0	5
Locomotive engines	2,000	0	0
Total	5,125	9	5

equal to 0·258*d*., or a little more than $\frac{1}{4}$*d*. per ton of minerals conveyed.

The gradient of the railway averages 1 in 128; but it is not uniform, being steeper opposite the upper part, and consequently flatter opposite the lower part of the sidings. In the sidings themselves the variation of gradient is somewhat greater, the steepest part near the upper end being 1 in 114 and 1 in 100, the latter only for a short length, and the flattest part 1 in 125. As they have followed, with but little modification, the accidental inclination of the main line, the question may be raised whether these gradients are the most suitable for the purpose, and such as would be adopted in laying out similar work in the light of past experience, and with unfettered choice. The Author believes it may be given as the opinion of the officers of the company, that while it would be inadmissible to adopt flatter gradients, it would not be advisable, having regard to the proper control of the trucks, and the frequent occurrence of imperfect breaks, to make them steeper than from 1 in 110 to 1 in 100. In the sidings now in course of construction at

Newport (Plate 3, Fig. 4) the gradient is a uniform one of 1 in 110, except in three places, where 1 in 100 is adopted, for the purpose of giving greater initial speed to the 'set' of trucks about to be sorted.

The traffic which passes through the Shildon sidings being consigned, as already mentioned, to upwards of two hundred different points of delivery, and there being only thirty-nine sidings for its classification, many of the receivers, too, being unable to take it in whole train loads, it is obvious that some sidings must receive traffic ticketed for several distinct places. It would, consequently, be desirable that such mixed trains should start on their journey with the trucks arranged in the same order in which the various receiving points would be reached, thus obviating sorting in their delivery; and herein it must be admitted that the present arrangements are imperfect, and that they fail in affording sufficient facilities for accomplishing this object.

To meet this want, it is proposed to lay down groups of four or five short sidings, connected with the lower ends of the groups C C and D D, in which a second sorting of the trains standing in the last-named sidings may be effected; and in continuation of each group of second sorting sidings to lay down one or two long sidings, where trains may be made up with the trucks arranged in proper order. The proposed sidings and contingent alterations are shown in Plate 3, Fig. 2. Their arrangement is, however, somewhat cramped from want of room; but similar, though more complete, sidings form part of the scheme of sorting lines at Newport.

As the traffic is now worked, the flattening of the gradient at the lower part of the sidings answers very well. But when the proposed alterations are effected, and when the trucks in sidings C and D will have to start by gravitation to pass into the second sorting sidings, and again to start from these sidings into the train-sidings, the initial steeper gradient will need to be continued throughout to the lower end. It is consequently proposed to raise the rails so as to adjust them to a uniform gradient of 1 in 114 from the western part of sidings B to the eastern end of the second sorting sidings, with the exception of short lengths of 1 in 100 introduced at places proper to facilitate the starting of the 'sets' of trucks. More break power will then be required to bring the trucks to a stand; but with the breaks in good working order, it is not apprehended that any difficulty will be experienced. Worn-out and useless or imperfect breaks are, however, too commonly met with, particularly among the 'foreign trucks,' and

increased care will be needed in their rejection. Near the eastern boundary of the works there is a long siding and weigh-bridge for occasionally testing the weight of mineral trains.

There is also near Shildon an assemblage (E) of sixteen sidings opposite the upper part of those already described, but on the other side of the main travelling lines (Fig. 3), chiefly for the reception and sorting of wagons, principally empty, going in the contrary direction, or towards the collieries. Being all blind sidings at the lower end, the trains when marshalled have necessarily to depart over the same rails by which the trucks enter them when being sorted. This leads to confusion and irregularity, so that it is intended to extend the blind ends, causing them to converge in two groups, and at each point of convergence to branch off into a group of second sorting sidings, beyond which long sidings will be laid for the marshalling of trains; these will then be able to pass out on to the main line without so much interference with the sorting operations.

The cost of working these sidings was, in the year 1873,

	£.	s.	d.
Inspectors and timekeepers	281	0	4
Thirty-nine sorters and wagon examiners .	2,398	17	10
Eleven wagon-greasers	408	6	2
One locomotive	1,000	0	0
Total	4,088	4	4

The number of trucks passing through these sidings exceeds, by about two hundred per day, the number passing through the sidings first described, the difference being occasioned by empties from the west side of the island returning to the colleries *viâ* Darlington and Shildon.

Much of the sorting of empties is rendered necessary by the trucks being owned by fifty or sixty different parties, each of whom consigns his trucks to some particular colliery. The work would be vastly simplified if the collieries could be supplied from a common stock of empties, the property of the North-Eastern Railway Company.

The length of these sidings is at present 9,200 yards, or 5¼ miles, and the land covered by them upwards of 7 acres.

The sidings for which the preliminary works are in progress near Newport, between the towns of Stockton and Middlesborough, are intended for the collection, sorting and marshalling in trains of the produce of the iron-making district of Cleveland.

The site selected having been formerly the foreshore of the river Tees, and the travelling lines being nearly on a level, the elevation required to perform the sorting by gravitation will be obtained by an embankment, the contents of which will be 450,000 cubic yards; of this quantity 320,000 cubic yards have already been deposited. The land to be embanked being contiguous to the blast furnaces of Messrs. B. Samuelson and Co., and being convenient for the deposit of slag, the bulk of the embankment is being formed with it by that firm without cost to the Railway Company. The arrangement is shown in Plate 3, Fig. 4.

As the sorting in these sidings will be performed by locomotives, unaided by gravitation, it is not proposed to notice them further. It may be proper to explain, that the coal and coke sidings are intended for the produce of the central Durham and Hartlepool district, which, as it comes on to the Darlington line at Stockton, is not sorted at Shildon.

When the sidings are completed, 'pick-up trains,' with the produce of the iron-making district, will leave the travelling lines by facing-points at P, and enter one of the four sidings Q, which have an ascending gradient of 1 in 80. Having cleared the main line, the engine will come to a stand, be uncoupled, shunted, and depart through the exit line R to the works for another load. A shunting engine will then take the train, or part of it from the siding Q, and after shunting in siding S, will push it through siding T, having an ascending gradient of 1 in 60, into siding V, whence it will return and repeat the process of feeding siding V out of the sidings Q Q. In the meantime, siding V will be emptied into one of the two sidings W W, the trucks being run down by gravitation, coupled together and just as they entered it.

The first sorting will commence in sidings W W, the train being divided according to the destination of the trucks, and each 'set' run into its appropriate siding in groups X X. Then will follow a second sorting in the sidings of the group Y Y, so that each train may have its trucks arranged in proper order for delivery; and lastly the trains will be formed ready for departure in groups Z Z.

The gradient, from the upper end at the point N to the middle of the train sidings Z Z at the point O, will be a uniform one of 1 in 110, except in three places where, to insure a greater initial velocity, 1 in 100 is introduced.

There will be a central line communicating with both groups of sidings, to give locomotive engines access to aid the motion of the

trucks when required, and a siding at M, having a weigh-bridge in the middle.

				Yards.
The aggregate length of the	first sorting sidings	X X	will be	4,795
” ”	second ”	Y Y	”	2,276
” ”	train sidings	Z Z	”	2,020
” ”	engine lines and other sidings		”	4,986
	Total		. . . .	14,077

or 8 miles. The land occupied by these sidings will be about 13 acres.

The sidings, completed and in progress at Shildon and at Newport, which form the subject of this Paper, sufficiently indicate the importance attached by the directors and officers of the North-Eastern Railway Company to a thorough sorting of trucks prior to the starting of a train. The Author would in conclusion submit, that all sorting operations, whether performed at the commencement, during the progress, or at the end of a journey, ought to be carried on in sidings provided for the purpose, in which the whole of a train may stand, and so free the main line from obstruction, involving delay and risk of accident.

The Paper is illustrated by several diagrams, from which Plate 3 has been engraved.

No. 1,421.—"On Railway Statistics."[1] By JOHN THORNHILL HARRISON, M. Inst C.E.

THIS Paper is a sequel to a former communication on the same subject presented five years ago.[2] The statistics of railway income and expenditure in 1873 are compared with those of 1868–69, with a view to ascertain more especially the effects of the altered policy towards third-class passengers, the lessons taught by past experience, and the policy those lessons suggest for future adoption.

The total expenditure on the railways of the United Kingdom amounted, in December 1873, to £588,320,308, having increased by £86,000,000 since 1867, or more than 17 per cent. in six years. Besides this increased expenditure on capital account, large sums have been paid out of revenue by some companies on works of a permanent character.

The net receipts rose from £19,631,047 in 1867 to £26,989,152 in 1873, or an increase of 37½ per cent. in six years. It is satisfactory to observe that the proportion of the net receipts to the total capital expended on the railways of the United Kingdom rose gradually from 3·91 per cent. in 1867 to 4·74 per cent. in 1872, and that the fall of this percentage to 4·59 in 1873 was not due to any falling-off in the gross receipts, but to the considerable increase in the working expenditure, arising, in great measure, from the high price of coal and of wages. This increased percentage of net receipts is calculated upon the largely augmented capital embarked in railways.

The prosperity of railways is most intimately connected with, and forms a very sensitive index of, the prosperity of the country. It is gratifying and encouraging to find that an amount exceeding the interest on the funded property of the country is now annually distributed among the investors in railway property, and that the amount so distributed has increased upwards of 37 per cent. in six years. In the same time the receipts from passenger traffic rose steadily from £17,936,000 to £23,854,000, or nearly 33 per

[1] The discussion upon this Paper, in conjunction with that upon the two preceding ones, was continued over portions of four evenings, but an abstract of the whole is given consecutively.

[2] *Vide* Minutes of Proceedings Inst. C.E., vol. xxix., pp. 322–372.

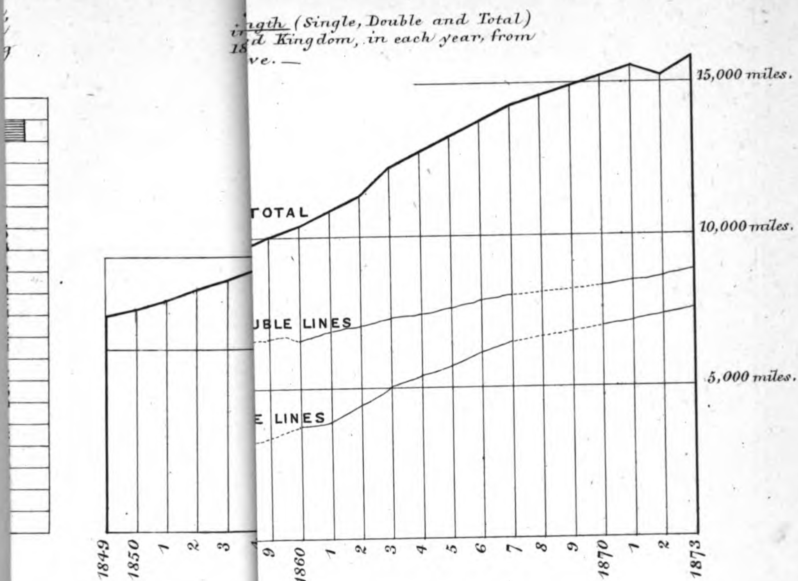
cent.; and the receipts from goods traffic from £21,544,000 to £31,822,000, or nearly 47 per cent.

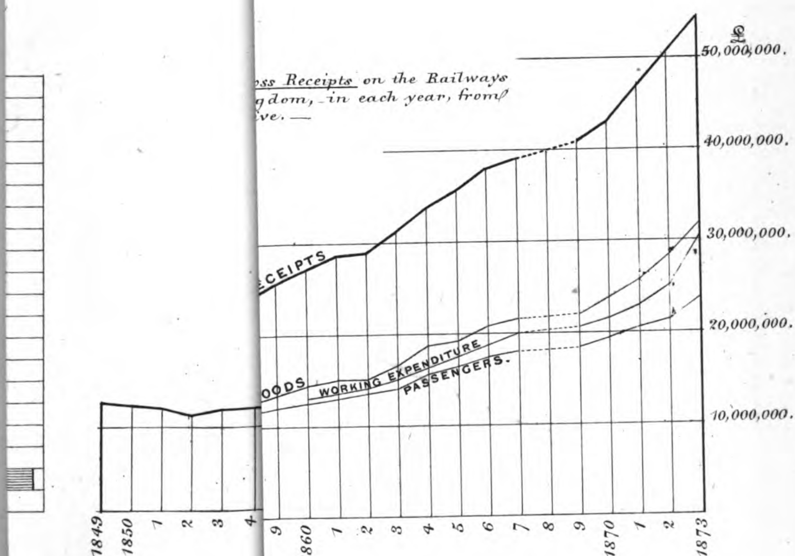
During three periods of six years each, from 1855 to 1873, the passenger receipts have increased respectively 25 per cent., 34·6 per cent., and 33 per cent., whilst the goods receipts have risen 41 per cent., 41·4 per cent., and 47·7 per cent. This shows a steady encroachment of the goods traffic in importance when compared with the passenger traffic, and an increasing occupation of the railways for the conveyance of goods. Thus in 1855 the numbers of passenger and goods trains were probably nearly equal, whereas in 1873 the goods trains were not improbably one-half more numerous than the passenger trains.

Between 1855 and 1873 the length of lines opened was nearly doubled; so were the passenger receipts. The actual number of trains running with passengers per mile opened was probably about the same in 1873 as in 1855, whilst the goods trains were one and a half as many in 1873 as in 1855. This might not be of much importance if the goods trains were evenly distributed over the country. But when their preponderance in certain localities, and concentration towards certain central points, are considered, the circumstances become of great importance, especially when the peculiarities of the traffic on each separate railway system are taken into account. This question of the growing preponderance of goods traffic on some railways has apparently an important bearing on the number of accidents from collisions.

To illustrate this subject and the Paper generally, a map of England and Wales has been prepared, on which the district of country occupied by each railway system is shown, as also the relative density of the populations in different parts of the country in 1871. The density of the population in a district stamps its character on the railway which occupies it. A comparison of this map with the geological map of England proves how remarkably that density is modified by the geological character of the country, and more especially by the coal formation. Next to the coal formation, the ports convenient for commerce and for direct communication with Ireland and the Continent are influential in forming large towns, London standing exceptional not only as the most important port in the kingdom, but as the centre of government and administration of the laws. Sea-bathing, again, is yearly becoming more important in its influence on the traffic of some railways.

The bulk of the railway traffic is interchanged between the centres of dense population, or it is dispersed from, and gravitates





...t 3.

THOS KELL, LITH. 40, KING ST COVENT GARDEN.

towards them.' The accumulation of traffic towards the centres of commercial and industrial activity multiplies the number both of passenger and goods trains, and greatly increases the liability to collision. In England and Wales accidents from collision cluster round such towns as Birmingham, Manchester, and Glasgow.[1] The occurrence of collisions in these positions suggests the importance of having lines of rail for passenger traffic alone, whenever more than a certain number of trains pass a particular point daily. This precautionary measure has been adopted on some lines, and should be enforced in every case. All railways are equally liable to certain descriptions of accidents; but the comparative freedom from collision on the southern lines, and on those parts of the northern lines where the traffic is somewhat similar to that of the southern lines, points very decidedly to this remedy as desirable.

Passing to the question of passenger traffic, and taking the same twenty railways that were selected in 1870 as fairly representing the entire system, it will be observed, on reference to Plate 4, Fig. 1, that the goods traffic on all the lines except the North London and the Great Northern, on which it is but little altered, bore a larger proportion to the passenger traffic in 1873 than it did in 1868–69, and that notwithstanding the large increase both in the number of passengers and in the receipts from them.

The total passenger receipts increased 19 per cent. in four and a half years from 1868–69 to 1873, and the number of passengers increased 47 per cent. during the same period.

Year.	Numbers.	Receipts.
1868–69	228,610,500	£14,016,900
1873	335,857,400	17,634,800
Increase or decrease	+ 107,246,900	+£3,617,900

This great increase both in numbers and receipts is due almost entirely to the greater facilities for travelling given to third-class passengers. Thus—

NUMBERS.

Year.	First Class.	Second Class.	Third Class.
1868–69	23,568,600	59,132,900	145,908,300
1873	27,456,000	50,390,000	258,011,200
Increase or decrease	+3,887,400	−8,742,900	+112,102,900
Per cent.	+17	−15	+77

[1] A map was exhibited indicating the places where such accidents occurred in 1873.

RECEIPTS.

Year.	First Class. £.	Second Class. £.	Third Class. £.
1868–69	3,469,900	4,393,600	5,543,800
1873	3,747,000	3,303,400	9,736,300
Increase or decrease .	+277,100	−1,090,200	+4,192,500
Per cent.	+8	− 25	+75

The net results are, therefore, most decidedly in favour of the liberal policy towards third-class passengers initiated in April 1872 by the Midland Railway Company.

It does not appear that the increase in the number of third-class passengers arose from any diminution of fares, but it was rather the result of the facilities afforded for travelling at the former fares, and of the extraordinary wages earned by the labouring classes.

The enormous sum of money paid weekly in wages in this country, more especially during the last few years, is essentially in constant circulation, and but little of it is arrested in its progress. After supplying the barely necessary food and raiment for the labourer and his family, the remainder is but too generally dissipated, and it is not altogether to be regretted that cheap railway travelling now competes successfully for the expenditure of some portion of this balance, as it affords a great amount of rational enjoyment and enlarges the mind of the million.

The example set by the Midland Company was only partially followed by other companies, and this affords an opportunity for useful comparisons. Whilst the third-class traffic has on most lines been largely recruited by desertions from the second class, the second-class traffic on the Bristol and Exeter Railway, and the South Devon and Cornwall immediately connected with it, has increased, a result apparently due to the very slightly increased facilities afforded by them for third-class travelling.

The railways on which different degrees of accommodation to third-class passengers have been given may be grouped as follows:—

(1st.) Those on which a minimum accommodation is afforded to the third-class passengers; viz., the Bristol and Exeter, the South Devon, and the Cornwall railways. On these—

The receipts from 1st class passengers increased 12 per cent. from 1868–69 to 1873.
„ 2nd „ „ 19 „ „
„ 3rd „ „ 36 „ „

(2nd.) Those lines on which third-class carriages are added to

about half the trains; viz., the Chatham, the Brighton, the South-Eastern, and the South-Western lines. On these—

The receipts from 1st class	passengers	increased	17 per cent.
„ 2nd	„	decreased	7 „
„ 3rd	„	increased nearly	36 per cent.

(3rd.) Those lines on which the majority of trains carry third-class passengers; viz., the Great Western and the London and North-Western. On these—

The receipts from 1st class	passengers	decreased	5 per cent.	on the G. W. R.
„	„	increased	4 „	„ L. & N. W. R.
„ 2nd	„	decreased	31 „	
„ 3rd	„	increased	98 „	

(4th.) Those lines which convey third-class passengers by every train; viz., the Midland, the Great Northern, and the Great Eastern. On these—

The receipts from 1st class	passengers	increased	7 per cent.
„ 2nd	„	decreased	36 „
„ 3rd	„	increased	101 „

These figures show the persistent character of the first-class traffic and the sensitiveness of the second class. To a majority of first-class passengers the amount of the fare is of minor importance, but comfort, convenience, expedition, and freedom from annoyance are everything. These rarely travel by railway for any enjoyment it affords them. Business, or the necessity of moving from one part of the country to another, alone draws them to the railways. It is not probable that a reduction of fares would materially increase the extent of this traffic, and therefore, neither as a question of consideration for their customers, nor of economy to the railway companies, does it seem advantageous to interfere materially with the first-class passenger arrangements.

The second-class passengers apparently consisted, in 1867–68, largely of those who were obliged to travel, and that expeditiously; but just in proportion as increased facilities were afforded for third-class travelling, so did they desert the second-class carriages and occupy the third. This surely is no reason why the remaining second-class passengers should be ignored. As a matter of policy, and for the convenience of these passengers, it appears desirable that accommodation for them should be retained, and that the fares should be approximated to those of the third class, so as to reclaim some of the deserters.

This line of policy was advocated by the Author, in 1870, in the following terms:—"It seems sound policy to afford ample facilities for all classes, and to make so slight a difference between the fares, that each class may rather aspire to the higher than the lower seat; there would not then be seen so many empty compartments in first-class carriages as there are now."[1]

Largely as the receipts from third-class passengers have increased since 1868–69, still the receipts from the first and second class traffic together amount to seven-tenths of that derived from the third class, and this proportion would be still larger if the receipts from season-ticket holders (chiefly first and second class) were added.

The first and second class traffic, therefore, deserves every consideration at the hands of railway companies.

As the railway companies that compete for traffic with the Midland Company to several large towns have arranged to charge similar first-class fares, whilst they retain the second class at reduced fares, it is not improbable that, for the through journeys, these lines will increase the number both of first and of second class passengers by the arrangement, and that possibly at the expense of the Midland Company. At any rate, the experience resulting from the trial will be very important. The competing lines are now carrying out fully the suggestions made in 1870: they are affording ample facilities for third-class travelling, and they have reduced the first and second class fares, so that there is now, comparatively, slight difference between them and those of the third class.

The increased facilities afforded for third-class travelling since 1872 have had the effect of increasing the passenger-train mileage receipts on almost every line; notably so on the Midland and on the Manchester, Sheffield, and Lincolnshire railways. This result was, on these lines, partly due to the considerably diminished number of trains (taken as) run over the entire length of the lines. On several other lines the increased mileage run has nearly, or altogether, counterbalanced any increased train-mileage receipts, which under different management might have resulted from the increased passenger traffic. The returns to the Board of Trade show that the Midland Company, up to 1873, studied the whole question of passenger traffic very closely, and carried out an improved line of policy.

The average number of each class of passengers travelling in each train seems to have varied but little from 1867 to 1873, on

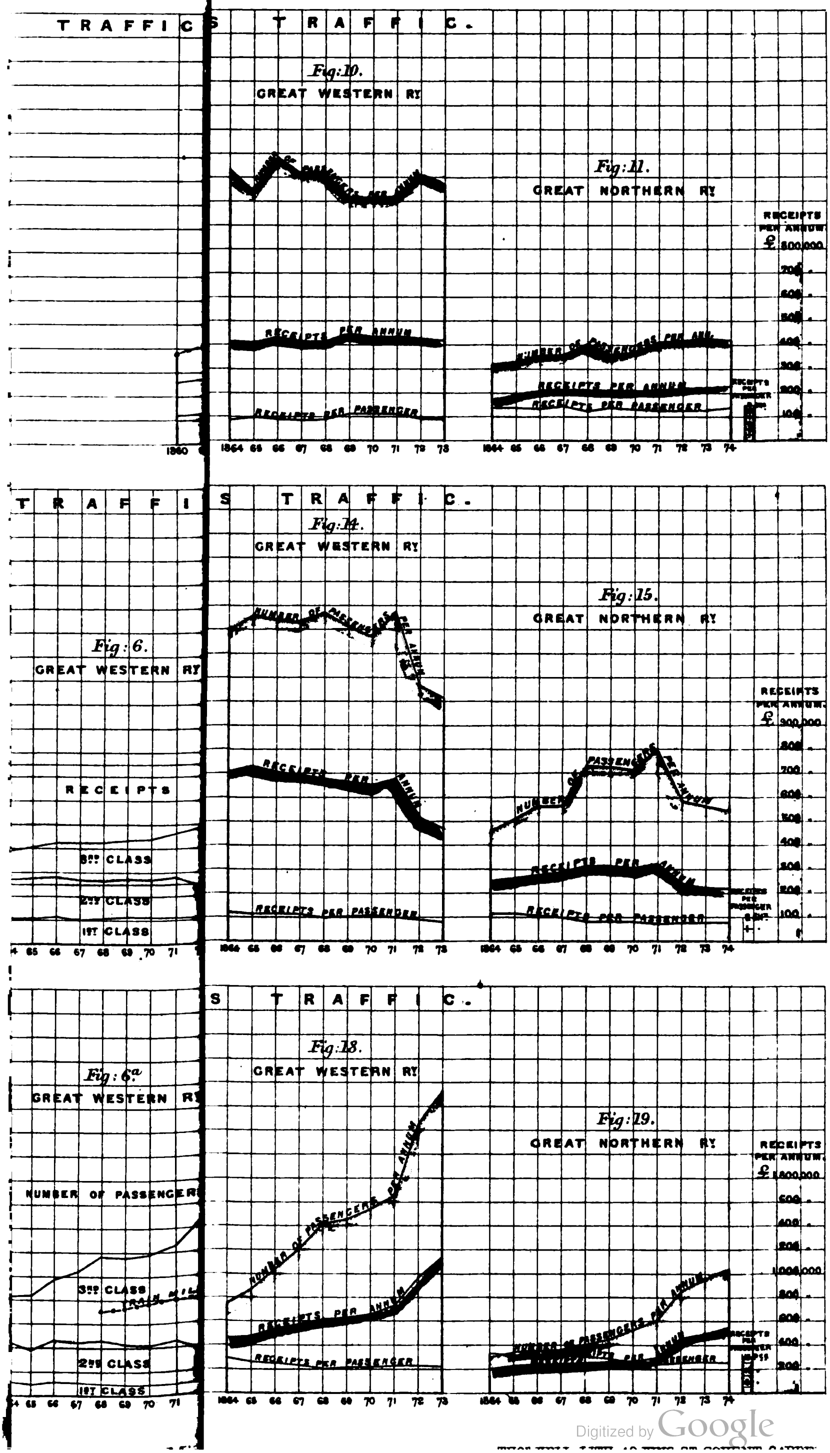
[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxix., p. 325.

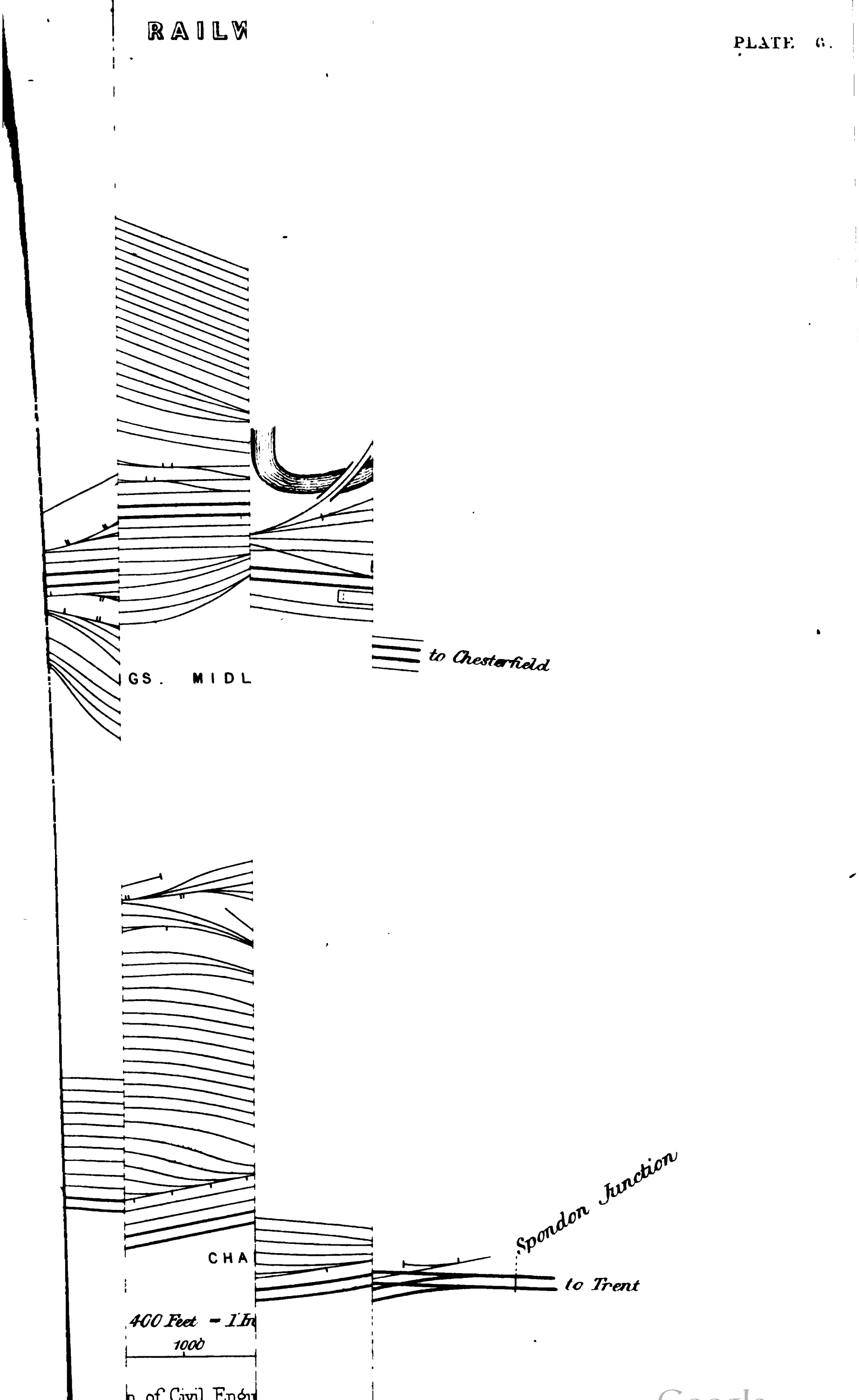
the lines running southward from London, and on the Scotch lines; but on the principal lines running northward from London there is a striking increase in the number of third-class passengers, and a marked diminution in the number of second-class passengers travelling by each train.

The communication is accompanied by a series of diagrams from which Plate 4 has been compiled.

[Mr. Findlay

Mr. Findlay said he had approached the discussion of the subject with diffidence and anxiety, knowing that many others of greater experience than himself could have more ably and fitly dealt with a question of such magnitude. Railway management, as generally understood by the public, was a matter which every one thought he knew more about than those who had the responsibility and anxiety of carrying on the work from day to day; therefore the apparent shortcomings of railways were always severely commented upon. When it was remembered that the system had grown from 30 miles between Liverpool and Manchester to about 14,600 miles, representing a capital of nearly £600,000,000 and an annual revenue of £60,000,000, it would be acknowledged that the magnitude and importance of the work could not well be over-stated; in fact, it almost approached the magnitude and extent of the government of the country itself. Of course it was necessary that the companies should spare no pains in organising a thoroughly competent and well-disciplined staff, and this they accomplished. From a return published by Parliament it appeared that two hundred and seventy-five thousand men were engaged in these undertakings; one hundred and seven thousand being employed in working the traffic, upwards of eighty-two thousand in the locomotive department, nearly sixty thousand in the engineering or permanent-way staff, and sixteen thousand in various other occupations. The manager of one of the most important railways in the kingdom had written to him to say, that since the subject was coming before the Royal Commission on Railway Accidents, a tribunal where it would be examined in all its details, and since there were still moot questions among the railway companies themselves, he ought to be careful, and not commit himself to a decided opinion upon these questions. Referring to the statement in the Paper that railway working was as hazardous as navigating the seas, his friend was prepared to prove that it was not nearly so dangerous, and he was quite prepared to accept that objection; also that although in the case of the royal train the system of electrical communication had been adopted with great success, all were not agreed as to that being the most perfect under all circumstances. More than twenty years ago the late Captain Huish affirmed that the time had come when railway companies ought to bow to public opinion and establish a communication between the driver and the guard. Public opinion had been humoured in the matter, but, as he believed, without any practical gain as regarded safe working. The use of


TRAFFIC
TRAFFIC.
Fig: 10.
GREAT WESTERN RY
NUMBER OF PASSENGERS PER ANNUM
RECEIPTS PER ANNUM
RECEIPTS PER PASSENGER
1860
1864 65 66 67 68 69 70 71 72 73
Fig: 11.
GREAT NORTHERN RY
RECEIPTS PER ANNUM
£ 800,000
700
600
500
400
300
200
100
NUMBER OF PASSENGERS PER ANN.
RECEIPTS PER ANNUM
RECEIPTS PER PASSENGER
1864 65 66 67 68 69 70 71 72 73 74
TRAFFIC
TRAFFIC.
Fig: 6.
GREAT WESTERN RY
RECEIPTS
3RD CLASS
2ND CLASS
1ST CLASS
65 66 67 68 69 70 71
Fig: 14.
GREAT WESTERN RY
NUMBER OF PASSENGERS PER ANNUM
RECEIPTS PER ANNUM
RECEIPTS PER PASSENGER
1864 65 66 67 68 69 70 71 72 73
Fig: 15.
GREAT NORTHERN RY
RECEIPTS PER ANNUM
£ 900,000
800
700
600
500
400
300
200
100
NUMBER OF PASSENGERS PER ANNUM
RECEIPTS PER ANNUM
RECEIPTS PER PASSENGER
1864 65 66 67 68 69 70 71 72 73 74
TRAFFIC.
Fig: 6a
GREAT WESTERN RY
NUMBER OF PASSENGERS
3RD CLASS
TRAIN MIL
2ND CLASS
1ST CLASS
65 66 67 68 69 70 71
Fig: 18.
GREAT WESTERN RY
NUMBER OF PASSENGERS PER ANNUM
RECEIPTS PER ANNUM
RECEIPTS PER PASSENGER
1864 65 66 67 68 69 70 71 72 73
Fig: 19.
GREAT NORTHERN RY
RECEIPTS PER ANNUM
£ 1,800,000
600
400
200
1,000,000
800
600
400
200
NUMBER OF PASSENGERS PER ANNUM
RECEIPTS PER ANNUM
RECEIPTS PER PASSENGER
1864 65 66 67 68 69 70 71 72 73 74


RAILW
GS. MIDL
to Chesterfield
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400 Feet = 1 In
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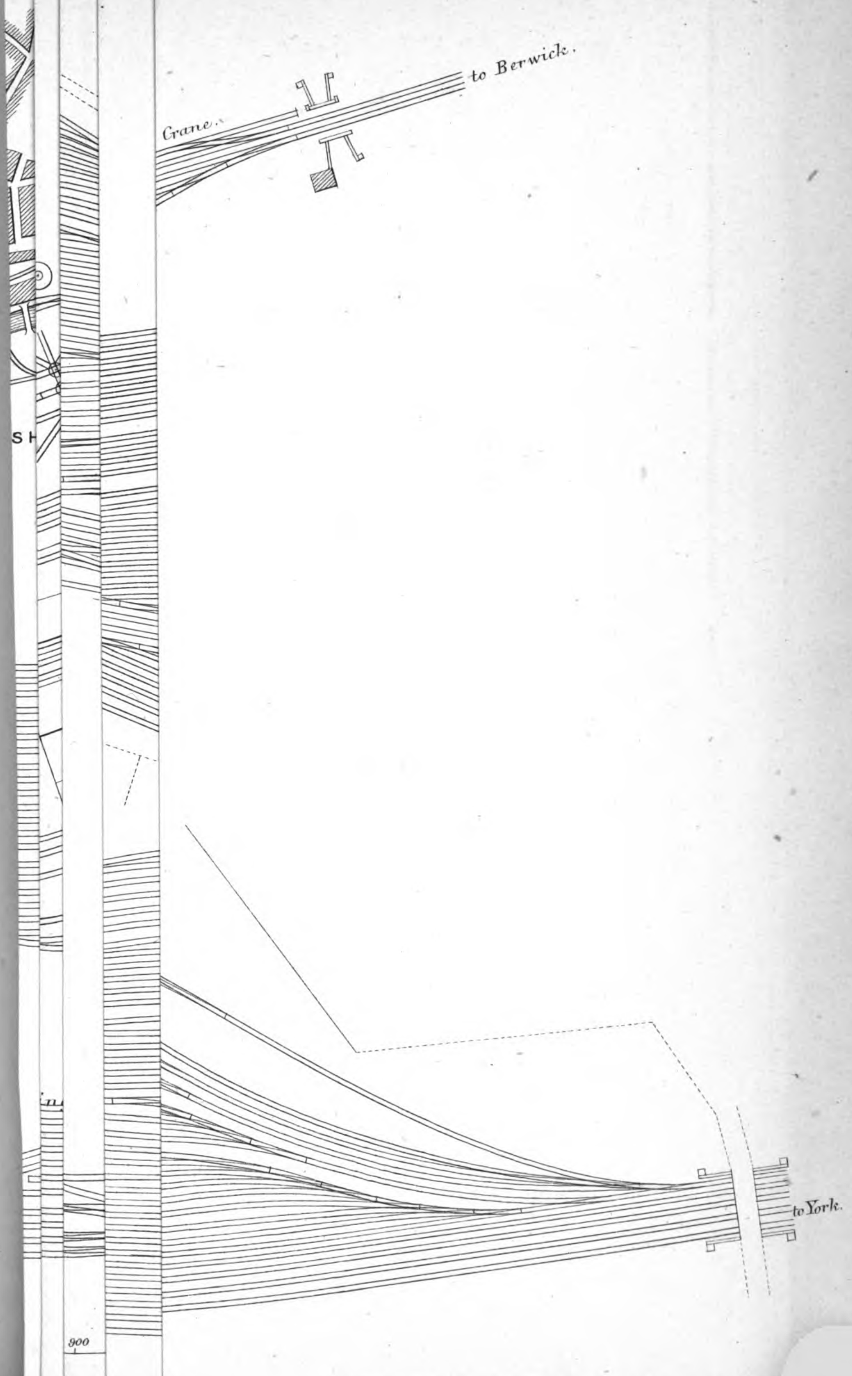
n of Civil Engi



THOS KELL, LITH. 40, KING ST COVENT GARDEN

the communication was so rare that he believed the railways might as well be without it. A fourth line of railway would shortly be completed between London and Bletchley, and it was then intended to continue the four lines from Bletchley to Roade. There would be a divergence from Roade, south of the Blisworth limestone cutting, to the east, so as to place Northampton on the main line, running through Lord Spencer's park and Lord Henley's demesnes, and reaching Rugby by a detour of about 2 miles. The Engineer, Mr. Baker, M. Inst. C.E., had informed him that the survey proved that the old London and Birmingham railway was so laid out as to secure the best route and the best gradients possible between those two termini. As a further proof of the foresight of the early workers, he might mention that in one of his first reports to the London and Birmingham company, Mr. Robert Stephenson suggested that there should be four lines, two for passengers and two for goods. It was also in contemplation to construct other relief lines on the North Union railway, commencing near Warrington, running through Wigan and on to Preston. These were necessary to ease the Scotch and the lake traffic, which it was so important to get through without interruption and delay. With regard to the increase in the weight of the traffic, in 1863 the 10 o'clock train from Euston was 312 feet in length and 123 tons in weight, while in 1872 the same train was 613 feet in length and 232 tons in weight (Plate 1). The number of carriages increased from eleven in 1863 to nineteen in 1872, but their weight and size had also increased from 6 tons 10 cwt. to 10 tons. Better accommodation had been afforded to the travelling public, by the addition of luggage compartments and of more space for the passengers, the carriage having been lengthened from 21 feet to 30 feet 6 inches, and the width had been increased from 7 feet 3 inches to 8 feet. Plate 1, showing the size of the limited mail from Carlisle to London, represented more accurately the normal increase in the weight of the train; for in that case the number of carriages was precisely the same. This had entailed the construction of more powerful locomotives. With the "Precursor," one of the most recent type, he had travelled with the royal train from Bushbury to Carlisle with fifteen or sixteen heavy saloon carriages. There was only one stoppage in the journey, and the speed averaged 36 or 37 miles an hour. Time was kept in going up Shapfell as well as upon level ground; and it was not necessary to run fast when going down an incline. Another question that had been a great deal under the consideration of railway men was the use of the continuous break. The

London and North-Western Company, without waiting to determine which was absolutely the best of the various classes of breaks, had determined to adopt Clark's, subject to modifications introduced by Mr. Webb. They believed that the ordinary friction-break possessed some advantages; it could be applied both by the engine-driver and the guard. Clark's break was very powerful and effective, but it was only desired to use it on an emergency. At the commencement of the journey it was ascertained that everything was in effective working order. The engine-driver and guard were instructed to depend upon the ordinary means of stopping the train, but if any extraordinary occurrence happened, they would then have within reach that powerful break. With regard to the block telegraph, in common with other companies, and in compliance with a pledge given to the Board of Trade to do so on the main lines, they had adopted that system to a large extent, but they still believed that the permissive system possessed some advantages. In 1862, when the country was in great anxiety to know the result of the communication made by the foreign minister to America with regard to the "Trent" affair, there being then no telegraphic communication across the Atlantic, a locomotive was kept in steam from the 2nd to the 9th of January, waiting the arrival of the special despatches to be landed at Queenstown, and sent by special train to Dublin and thence by steamer to Holyhead. The London and North-Western Company had not then adopted the block system; but, by means of the ordinary telegraphic communication from station to station, the train with the "Trent" despatches was run from Holyhead to Euston, a distance of 264 miles, in five hours, an average speed of 53 miles an hour being maintained throughout the whole journey with one stoppage only, at Stafford, for the purpose of changing engines. During the passage of that train there was not the slightest interruption or delay of any kind. Although there had been changes of system, in consequence of the increased extent of traffic brought upon the different lines, the old method ought not hastily to be condemned, which enabled a feat of that kind to be performed, and on which the traffic of the country had been admirably conducted for many years.

The system of sidings proposed to be adopted at Edgehill and Crewe had met with the general approval of the directors, who had purchased the land for the purpose; and if it proved successful, of which he had no doubt, it would be adopted at all the important centres, so as to enable the goods trains to be classified, not only in sections, but also in station order. With reference to

the speed and regularity with which the goods traffic of the country was carried on between distant places, the Paper contained a comparison of what was accomplished in England and in France. The public understood that branch of the work very little. It was common to hear persons in private life refer to the great success that had attended the working of the Post-office service; and it was suggested that the Government management of the railways might be equally successful. Without attempting to disparage the working of the Post-office, he contended that the Government were merely agents in the matter—the collectors and deliverers of the letters—while the railways performed the actual service between distant places. He thought that more credit was due to the railway service than to the Post-office for the manner in which the enormous goods traffic of the country was carried on, measured as it was by hundreds of thousands of tons. Goods were collected at the merchants' doors and delivered at the various warehouses of the country with the same regularity and punctuality as characterised the delivery of letters.

With regard to the conveyance of third-class passengers by all trains, the experience of the London and North-Western Company was, that while there had been a large increase of passengers travelling short distances, there had not been a corresponding increase of persons travelling long distances. Third-class passengers were discriminating, and where there was a fast train between any two given points, they generally chose that in preference to any other. The result was that nearly all the fastest trains had to be duplicated to provide the necessary accommodation and prevent delay, which had added largely to the expenses. Although, perhaps, it was politic and desirable at the time to extend the third-class accommodation, he was not sure whether that had not been carried too far, and whether railway companies would not find it eventually desirable, at least in their own interest, to exclude third-class passengers from some of the most important trains. He believed that the first-class fares were sufficiently low. The only analogous case in other countries to which he could refer was that of Belgium. A very low tariff was at first settled by the Belgian government. A modification of that tariff was adopted between 1866 and 1871, when the fares were brought down to a still lower scale, and graduated according to distance, the longest distance being charged at the lowest rate. After an experience of five years it was found that the system of low fares had resulted in a large loss of revenue to the State railways, and then it was determined to advance them in some

cases to a figure somewhat higher than that at which they stood in 1866. It might be said that the State railways in Belgium afforded but little comparison with English railways; but that was an instance to which he could refer as an illustration that reduction of fares had not been profitable, and had been subsequently abandoned.

Several points in connection with the working of railways had not been mentioned in the Papers, but he hoped opinions would be elicited in the course of the discussion upon the following among other matters:—(1.) Was it desirable that refuge or shunting sidings should be entered by facing points, with a view to save time and to facilitate the working of traffic? (2.) Did the companies on approaching stations depend altogether upon what was called the Home and Distance signal for protection, or did they, as a general rule, adopt the system of blocking back to the block station immediately preceding? (3.) To what extent were trains signalled in advance by the use of the "Be ready" signal, so that an important train proceeding along the line might be advised from one station or one signal block to another? (4.) Should assistant engines up steep inclines be used in front or in the rear of the train, or should a train load be strictly limited to the capacity of one engine? (5.) What were the best precautions to adopt for goods trains breaking loose, which they unfortunately sometimes did in ascending steep inclines, and running backward? (6.) Was it desirable, looking to the enormous increase in the traffic of the principal railways, to reduce the speed of the trains?

Mr. FOOTNER said, in reference to the gridirons, that of course trains on entering a station were seldom so disarranged as was represented on Plate 2. The numbers had been taken at random, so as to show what could be done when the trains arrived in very bad order. Still he had frequently known in a train of thirty or forty wagons, there were not more than two for the same place. The method of working the gridirons indicated in the diagram need not be rigidly adopted in all cases. The plan could be modified to suit the particular train expected. In some cases the necessary marshalling might be done by splitting up the train in the upper gridiron only, and letting it run through the lower one. Such modifications of the general principle were soon learnt by the shunter, and indeed practically suggested themselves to him as he became acquainted with the system. The form of gridiron at the lower end of the system at Edgehill (Plate 2) had the disadvantage of sharp curves on the outside lines, while the centre line was straight, so that some-

wagons encountered a greater resistance in passing through than others. That peculiarity would be advantageous in the case of wagons known to run badly, which might be allowed to take the inside lines, the others taking the outside. The upper gridiron was longer, the wagons had to encounter the same radius of curvature, and the same change of direction on each of the sidings. It was an advantage that one travelling line was common to all the sidings; for horses (which would be required during hard frosts and strong head winds) could work clear of the sidings. Experimental gridirons were laid down in Liverpool with an average gradient of 1 in 80; but they were steeper through the points and crossings, and also at a short distance above the points and crossings to ensure the trucks starting quickly. When a number of wagons were coupled together in long sidings the good runners assisted the bad ones; but when they were separated it was necessary to have such gradients as would enable bad runners to travel by themselves. The gradients of 1 in 80 were steeper than the well-known sidings at Doncaster, Shildon, and other places. The former were for mixed traffic, while the latter were almost entirely for mineral traffic. In the case of mixed traffic the varied construction and variable condition and loading of wagons required steeper gradients. At Accrington shunting had been successfully done for many years off a gradient of 1 in 47, and accidents were very rare. The men appeared to have thorough command of the wagons. He had seen thirty-seven wagons taken up that incline, and shunted in ones and twos, in twenty-seven separate shunts, and in ten minutes the line was again clear. The sidings were not well placed, having been added to from time to time, and the points and crossings were much scattered. In this instance one foreman, one uncoupler, and one pointsman were employed, and four shunters to accompany the trucks. The work was done in the usual way, the men not knowing that anybody was timing them. One difficulty was involved in the adoption of the system of shunting by gravitation which seemed to deserve attention —the possibility of the wagons running away by accident or design. This was particularly the case at Edgehill, where the lower end of the gridirons communicated with the rest of the station, where miscellaneous work was going on. To meet that difficulty, and to catch runaways, he laid down a hook attached to a heavy chain coiled in a pit, like a ship's cable in a chain locker. It was worked by a lever, but could be made self-acting, and was set at the height of the axles of the wagons, so that the leading axle of a runaway truck would run into the hook and

draw the chain gradually out; and the retarding force of the chain dragged along the ballast was sufficient to stop the vehicles before they crossed or joined other sidings. The velocity which a wagon would acquire in going through the gridiron was not more than about 15 miles an hour. At Crewe, the goods traffic was turned off the passenger lines close to the passenger station; and on entering the yard the trains had to run at once upon the sidings, which interfered with the free movements of the shunting engines. One object of the plan to be adopted at Crewe was to separate the goods and passenger traffic, and to provide independent goods lines both for approaching and for leaving the goods station.

Mr. Rapier said the Institution was much to be congratulated upon having three Papers of so opportune a character presented at the same time. It had been said that Mr. Findlay's Paper was a defence of the railways; but he thought the case might have been put much more strongly as regarded the important services rendered by them to the public.

The statistics in Mr. Thornhill Harrison's Paper were most valuable. The increase in the dividends to shareholders from 3·91 per cent. a few years ago to 4·74 per cent. at the present time indicated satisfactory progress; but it was only progress. No one who had witnessed the splendid service of the London and North-Western, the Great Northern, and other leading lines, could say that less than 10 per cent. dividend was deserved. Railway men ought to be cautious about throwing away any part of their prosperity. The recent action of the Midland Railway Company in that respect was fraught with danger. Fortunately the example had not been imitated. If other companies had followed the example, or, still worse, had adopted retaliatory measures, a succession of disasters would have ensued. Instead of that, the other companies had adopted very much the policy shadowed forth by Mr. Harrison in his former Paper, namely, that of making quick and cheap travelling possible, but preserving all the classes and arranging the fares so as to secure the best net result. This line of action was the most gratifying feature which had been seen for many years past in railway competition. To reduce the first-class fare was simply a wasteful proceeding. It made little difference to a first-class passenger going to Edinburgh whether the fare was 10*s.* less or not. Any reduction in that direction ought to be postponed until after many wants had been attended to.

The inability of railway companies to afford such reductions at present was strikingly illustrated by the other Papers. The block system had been hardly perfected, when a further ex-

penditure was found necessary for the goods traffic. In a Paper before the Institution last session, he drew attention to the desirability of keeping the goods shunting entirely free from the main line;[1] and he gave some instances of a cheap way of accomplishing that, by making new passenger lines outside the existing goods yards, leaving the goods traffic in possession of the field. Mr. Cudworth and Mr. Findlay had gone a step further in dealing with what might be called congested traffic. The question of the cost of the proposed gridiron sidings was extremely interesting; and he hoped the Authors would give some particulars on that subject. The mere statement of a proposal to take 50 or 60 acres of land near a populous place like Liverpool or Manchester might startle some directors: still the case was such a good one that it was a pity not to state it in its entirety. At Shildon the expenses of working were put at ¼*d.* per ton. Taking 16 acres of land at £1,000 an acre, the cost would be £16,000, involving an annual interest of £800. Then the cost of 10½ miles of sidings at £2,000 a mile would be £20,500, involving probably 5 per cent. for maintenance, or £1,025, and also £1,025 for interest, making a total of £2,850, which would have to be added to the £5,125, making a total cost for the traffic passing through the sidings of ·4*d.* per ton. So at Edgehill, taking the number of acres of land and the number of miles of siding, the cost would be ¼*d.* per ton capital charge to be added to the probable ¼*d.* per ton, as in the case of Shildon, for the working expenses. But even when all those expenses were incurred, that method of shunting would be far cheaper than by the old mode of fan sidings, because there would be less shunting mileage. On arriving at a station the whole train had to perform the journey to the farther end of the station once, and each individual truck had to perform the journey to the other end once; in other words, every truck had to traverse the shunting space twice. Far more than that had to be done in making up a goods train without such appliances. But if the expense was all additional, the advantage of having the trucks in perfect station order would seem to render the adoption of the system desirable. This would be especially the case in a cross-country route. With one of these he was familiar, namely, that from Ipswich to Liverpool. With the proposed arrangements for shunting sidings, even if the trucks had to go through the operation six or eight times, there would only be a total charge of 3*d.* or 4*d.*

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxviii., p. 183.

per ton for the journey of 200 miles, in exchange for which the advantage would be obtained of delivery many hours earlier, and possibly a whole day. The importance of speed in the delivery of goods was very great, and the companies deserved credit for the facile manner in which they obtained it. A still more important thing was to keep the lines clear at roadside stations, and to have hardly any shunting at those stations. This could be accomplished by the proposed system, because the train arriving with its trucks in station order had simply to back so many into one of the sidings and then to start again. By relieving the roadside stations of the shunting traffic, that *bête noire* of doubling the line could be postponed. Every expedient, such as the adoption of the block system, separate goods yards, sorting gridirons, fast and slow relief lines, and the like, should be adopted before entering upon any general system of making separate lines for goods and passenger traffic.

Considering the small number of trains on the London and North-Western line between Wolverton and Rugby, it was almost a matter of regret that the step should have been adopted so soon. This had been taken of course on the opinion and by the mature advice of the experienced officers of the company, so that it would ill become him to say anything against it. It was a gratifying circumstance, however, that the step had been resolved upon and taken before the popular clamour on the point arose. If this were once yielded to, railways would never pay a dividend. There was no one so unreasonable as the English railway traveller, who as soon as he entered a railway carriage began to exercise his privilege of grumbling, if it was only at a train being ten minutes late on a long journey. No sympathy was ever expressed for an unfortunate company, with its half-filled carriages, slippery rails, and bad weather. A passenger was impatient if he could not find the exact class of carriage he desired, and the precise kind of accommodation he wanted in that class.

Parliament had reserved one alternative in every railway Act, but of which railway companies had not hitherto availed themselves; namely, that if at any roadside station there was not sufficient room for the passengers presenting themselves, a selection was to be made according to the length of journey intended and the priority of the issue of tickets. How astounded a passenger would be to be told that there was no room for him in the train, and that his ticket being one of the last issued, he could not proceed. Such a thing was perfectly reasonable. If a man found an omnibus full of passengers he did not think of abusing the

conductor or the driver, but waited for the next conveyance. It ought to be the same with railway trains. He often travelled upon a line where the carriages were never half full, there being twelve or fourteen carriages, whereas the passengers could be easily put into two or three. Sometimes, no doubt, two or three carriages would not hold them all. Then they should be left behind to wait for the next train. It was a good thing that the Institution was directing attention to such points. He hoped that care would be taken of every source of revenue, and that improvements would be made that would effect a direct saving and increase the carrying capacity of trains, and therefore the earning powers of railway lines; and that all questions of reduction of fares, duplicate lines, and fancy carriages (for which there was no room in this country, the journeys being so short) would be postponed until the railway companies shared some of the general prosperity which the country had enjoyed during the last twenty years, mainly through the instrumentality of the railways.

Mr. Webb maintained that additional lines between London and Rugby were necessary. Goods could not be delivered at midnight, and passengers would not travel just when the company chose to take them. The company had to put on trains to suit the public; and taking into account the excursion trains in the summer, and the special trains, working as they did with the block system, he did not see how many more could be run on two rails. If Mr. Rapier would observe the relief afforded by the third lines between Bletchley and London and Rugby and Nuneaton, he would, if he were traffic manager, be glad of the additional lines about to be made. With regard to the proposal to limit the trains to the power of one engine, those who made it could know but little of railway working. On arriving at the bottom of Shapfell, the alternative would be to divide the express into two parts, and put on two engines, and then at the top to reunite them. But the traffic could not be worked in that way. During twenty-five years he had not heard of a single accident to a passenger or a servant from the practice of putting an engine behind the train to help it up the incline, and he therefore thought it would be foolish to alter the system. The shunting sidings would relieve the vast number of engines on the London and North-Western system that were doing nothing but shunting, for which no credit was given in the record of work done. In comparing the locomotive expenses on the North-Western with those of other lines, it became a moot question, what was a train mile? His chairman took good care that he should manufacture

none. If he had to employ two engines for a train he was only allowed mileage for one. There were one hundred and seventy-one engines employed on the line in shunting, for which he had no credit in train mileage. The train miles were calculated on the actual distances run by the trains, pure and simple. When the proposed shunting sidings were formed he hoped there would be a marked difference in the locomotive expenses. The actual weight of the trains was not shown in the reports. A passenger carriage was calculated at 5 tons, its real weight being 10¼ tons without the passengers. The calculated weight of an empty wagon was 3 tons, of a full wagon 6 tons, and of a mineral wagon 8 tons: the weight of a mineral wagon, however, when full, was 13 tons, and the others in proportion. He had taken out the work done by the small type of wheel (5 feet 6 inches) employed on the line since May 1874 for the express trains between Crewe and Carlisle. Accepting the guard's statements as to the weight of the train, it seemed that he had made a powerful engine for very little purpose. The average weight, according to the guard's statement, was 59·6 tons, the number of carriages 11·7, consumption of coal per mile 32·2 lbs.; but the actual weight was 140 tons, besides the engine and tender. Government had given a standard for railway accounts, and he thought there should also be a standard for train mileage and the weight of loads hauled; comparative statements would then be of some value. The first small-wheel engine took the royal train in May 1874, and had been in constant use ever since. When recently brought into the shop, after running 35,000 miles, no repairs were wanted, and to all appearance it would run another 35,000 miles before requiring any. He should be glad to hear what could be said with regard to the opposite system, viz., a great weight upon one pair of wheels of very large diameter—a system he believed that did more harm to the permanent way than a greater weight for adhesion equally distributed between two pairs. From his own experience he was inclined to believe that an engine with four small wheels was best adapted to the working of heavy express traffic. The engine with wheels 5 feet 6 inches in diameter was made for the exceptional gradients between Crewe and Carlisle. He found that to take the same train to London the engine with wheels 6 feet 6 inches in diameter did the work most efficiently. The first of those engines was now running; and before the 1st of May he hoped to havo all the heavy express trains between Crewe and London worked with that class of locomotive. With reference to the question of break-power, about which railway com-

panies were supposed to be indifferent, if they adopted any one system, and used it for ordinary stoppages, he felt certain that they would some day fail. The plan on the London and North-Western line was to have a break on the tender, under the control of the driver, another on the guard's van, under the control of the guard, and an extra break (Clark's) under the control of both guard and driver, but not to be used for ordinary stoppages. In approaching a terminal station like Euston, King's Cross, or St. Pancras, if the drivers were accustomed to the continuous breaks, capable of stopping the train in ¼ mile, what would be the consequence of the breaks on any occasion becoming inoperative? He thought the regulation of the London and North-Western railway a wise one. At the first stoppage of the down train at Willesden the extra break was ascertained to be in working order, and then, for all the usual stoppages, the ordinary break was relied upon. On the Metropolitan, where there were more stations than miles of line, the extraordinary working might require extraordinary means.

Mr. J. A. Baynes said, with regard to railway statistics, that the form of account laid down some years ago by Act of Parliament for general adoption by railway companies, was, no doubt, a good thing in itself; but there were several matters not provided for, on which a great diversity of practice prevailed. For instance, train mileage was to be given, but how was it to be made up? No basis was laid down, and it was open to every company to arrive at this in its own way; and if the train miles of the various railway companies were examined, it would be found, he thought, that they were not made up on the same basis. It was desirable that there should be uniformity of practice in that respect. Then again the accounts of the companies did not reveal the actual work done. They gave the number of passengers, and the receipts from the passengers of each class, but they did not give the average distances which the goods and passengers were carried, nor the tonnage of goods and minerals, so that it was impossible to tell what work had been done. All that was known was that a certain gross amount had been received in respect of goods traffic, from which the terminals were deducted, and then the net amount was put to the credit of the revenue account. It was desirable, in order to arrive at the economics of railway working, that the statistics should be both complete and uniform. What was the true test of economic working? Was it the percentage system—the proportion of the cost to the receipts? That was the old-fashioned method, and it was still used by railway people, though not stated in the accounts as it used to be. It told

favourably on lines that had a great deal of traffic, and unfavourably where the traffic was comparatively poor. Was it better to state the cost at so much per mile of open line? Clearly that would not show what traffic had been carried over the railway. Nor was the amount per train mile a perfect test. By running a good many train miles, and, by increasing the divisor, the result would be reduced—so appearing to be economical, when the work was in fact expensive.

With regard to the Indian railways, the Government had laid down that the accounts should show the fares for passengers, and the rates for various classes of goods, and the ton-miles represented by their journeys. This they did; and they also showed the number of train miles run, so that the goods' work done could easily be stated as so many tons carried 1 mile. That appeared to him to be, on the whole, a very fair way of showing the result. There was also wanted a division between coaching cost and goods' cost; and that was not done in any railway with which he was acquainted. It might be difficult to ascertain; but he thought that an approximation could be obtained, so that it would be pretty accurately and clearly demonstrated what was charged to the public for carrying a passenger 1 mile, and for carrying a ton of goods 1 mile, and also what it cost to do the work. If the accounts were put into such a shape as to give the foregoing information, there would be a fair approximation towards a scientific way of ascertaining the cost of working a railway, and then the companies would better know what they ought to charge the public for the service rendered. Under present circumstances, the companies were very much in the dark. The London and North-Western railway was an empire of locomotion in itself, having carried last year 43,503,353 passengers, and 24,017,638 tons of goods, the train mileage being 30,474,401. How far those passengers and goods were carried the accounts did not show. The average mileage in this country both of passengers and goods was much shorter than that of the Indian lines. He thought the average mileage here would be about $\frac{1}{8}$th or $\frac{1}{7}$th of that in India. The smaller number of tons carried in India would therefore represent a proportionately greater amount of work done. For the second half of 1873 on eight of the principal Indian lines the following were the average results:—

	Per passenger per mile. *d.*	Per ton per mile. *d.*
Gross receipts	0·378	1·14
Working cost	0·187	0·65
Net earnings	0·191	0·49

The average distance travelled in 1873 in India was about 60 miles for passengers and 214 miles for goods.

The growth of the commerce of the United Kingdom and of the railway system, during the last few years, especially since 1870, might be illustrated by a few statistics. The value of imports and exports had expanded from £185,127,897 in 1851, to £377,117,522 in 1861; and from £547,338,070 in 1870, to £682,292,137 in 1873; showing an increase between 1861 and 1870 of 45 per cent.; and between 1870 and 1873 of 24·66 per cent. The gross receipts on railways enlarged from £14,997,459 on 6,890 miles in 1851 to £28,565,355 on 10,865 miles in 1861, and to £45,078,143 on 15,537 miles in 1870, the last increase being equal to 58 per cent. In the period from 1870 to 1873 there was only an additional mileage opened of 4½ per cent. The total capital invested in 1873 was £588,320,308, or an addition of 11 per cent., showing that a great deal was spent upon old lines, no doubt for further accommodation, sidings, stock, &c. The number of passengers had increased 125,315,790, or 37·97 per cent.; and the tons of goods conveyed by 21,588,739, or 12¾ per cent., over 1871, there being no figures of tonnage for 1870. The passenger receipts had increased by £4,551,981, or 23·58 per cent.; the goods receipts by £7,706,370, or 31·96 per cent., and the gross receipts by £12,663,857, or 28·09 per cent. In the working expenses there had been an enormous development; and to this he wished to direct special attention. The gross receipts had risen 8·4 per cent. in 1871 over 1870; 8·9 per cent. in 1872 over 1871; and 8·5 per cent. in 1873 over 1872. The working expenses had increased 6·6 per cent., 13·8 per cent., and 17 per cent.; so that, to earn an additional 8·4 per cent. of gross receipts, there was an additional working cost of 6·6 per cent. in 1871: to earn 8·9 per cent. there was a working cost of 13·8 per cent. in 1872: and to earn 8·5 per cent. there was a working cost of 17 per cent. in 1873. The total working expenses had increased from 48 per cent. in 1872 to 53 per cent. in 1873; and if the year 1874 were taken, for which the Board of Trade returns were not yet issued, it would be found that they had risen to 55 per cent. on several of the principal railways in the country, while the train-mile rate had increased from 2·57*s.* in 1870 to 3·12*s.* in 1873. The cost of the additional work was 37·67 per cent. of the additional traffic in 1871, 71·9 per cent. in 1872, and 99 per cent. in 1873, and in the year 1874 it would be still higher, as increased business had coincided with reduced net earnings and diminished dividends. In 1872 the excess in the cost of working was produced by the higher price of coal and iron. This was also

the case in 1873, and it partly extended to 1874. Of the increased percentage in working cost from 48 in 1870 to 53 in 1873, 4 per cent. was due to locomotive and 1 per cent. to maintenance. In the last half of 1874 there had been a considerable falling-off in the price of coal, but there was an increase under the head of "Permanent Way and Traffic," amounting to nearly 2*d.* per train mile. This seemed to show that the additional traffic over the railways was necessarily occasioning greater cost in maintenance, and steel rails were now being largely used. There was also the expense of the block system, as well as the higher price of labour in all departments. The block system might not be considered a permanent charge, but it would probably cause a large additional annual cost. These facts and figures seemed to show that, instead of a reduction in the price of railway carriage to the public, there ought rather to be an increase, if the cost of production was to be taken into account. The average amount received per first-class passenger in 1870 was 2*s.* 5·8*d.*; in 1871 the amount was 2*s.* 3·9*d.*; in 1872, 2*s.* 3·8*d.*; in 1873, 2*s.* 3·4*d.* There was an increase in the second-class receipts in 1871 over 1870; but in 1872, early in which year third-class passengers were conveyed by almost all trains, the second class was largely emptied into the third, leading to a considerable reduction in the second. The receipts per second-class passenger had diminished from 1*s.* 3·9*d.* in 1870 to 1*s.* 1·6*d.* in 1873; and the receipts per third-class passenger had increased from 7·9*d.* in 1870 to 8·1*d.* in 1873. The general effect had been to bring down the average amount paid by each passenger from 11·9*d.* in 1870 to 10·06*d.* in 1873. He gathered from these facts that the alteration had been rather injurious than otherwise to railway companies, though the public might have benefited thereby. In regard to the recent action of the Midland Company in abolishing the second class, it seemed to him that as there were three classes in society generally, there ought to continue to be three classes in railway accommodation. It might be said that there were only two classes in omnibuses, inside and outside; but the railway ought to accommodate people who were in the habit of travelling in cabs and carriages as well. The first-class passengers paid nearly four times as much as the third-class; and railway companies could not afford to disarrange or disgust any of their customers. The truer policy would seem to be to reduce somewhat the fare and improve the accommodation of the second class, which most companies were doing.

Sir JOHN HAWKSHAW, Past-President, said it was obvious to those who had considered the question, that the cost of providing railway

service was now an unknown quantity; it was not likely to grow smaller, for wages would not become less, nor was the price of materials likely to be permanently less. The demands made by the public were becoming more and more exacting. Reasonable or unreasonable, they would certainly lead to a great deal of additional expenditure on the part of railway companies. In that state of things the charge for the service must necessarily bear some relation to the cost of providing it, and he thought it a most unwise thing on the part of any railway company, at the present time, to reduce the charges to an important extent. It would be more prudent to wait and see what the service would cost; he was quite sure that railway companies did not know it at present. Looking to the future he could not see where all the requirements of the public and the Board of Trade would ultimately lead. There was one important matter to which but little reference had been made, namely, the block system, which was now being applied on most railways, having been as it were forced upon them. It would certainly cost the railway companies a large sum of money, not only in the outlay of capital, but also for the additional number of servants required. It would also create considerable difficulty in carrying on the traffic. He had no hesitation in saying that if the block system were fully established upon all railways, it would diminish their power of carrying traffic to a large extent. That could only be met either by declining to carry the traffic, which the companies could not do, or by making other lines and providing other means of carrying it, involving, of course, a larger outlay of capital. As to whether the block system itself was the best thing that could be devised for the safety of the public, he had not considered the matter so thoroughly as to be able to give a decisive opinion. There were certainly one or two points that militated against it, to the convenience if not to the safety of the service. Punctuality was one of the most important features of railway traffic, and the block system would not increase that. He was lately on the Lancashire and Yorkshire railway, and in going from Manchester to Bolton in less than ½ mile he was blocked three times, and kept waiting some minutes on each occasion. In returning by another portion of the railway at Miles Platting he was stopped in the same way by another block; until, in order to arrive at his journey's end—about ¾ mile distant—there appeared to be no alternative but to get out of the train and take a cab. It was quite evident that upon a busy line of that kind the block system must lead to such interruptions and delays as absolutely to destroy in some cases the possibility of one train

running in communication with another. Under such circumstances the train would have either to leave without the passengers who were to be carried by it, or try to make up for lost time by increased speed. It yet remained to be seen to what extent the block system would be conducive to safety; he was quite sure it would greatly increase the expense, and diminish the power of conveyance of traffic, and would lead to the absolute necessity of making more lines of railways. Railway managers and directors, therefore, should be careful not to diminish their charges. The time might come when they would have to raise them. Of course there might be questions as to whether low fares would increase the traffic, &c.; but he was not dealing with those. He merely contended that in the face of the absolute and positive increase of expenditure it was not wise or prudent in any company at present to reduce its charges. Apart from the considerations he had mentioned it was necessary to look forward ten or fifteen years, and if the traffic increased as it had done, and the block system was to be everywhere established, he had no hesitation in saying that the present railway system would not be able to carry the traffic. Railway companies, therefore, should be prepared for a large expenditure in the shape of relief lines or duplicate lines, or lines to carry minerals or goods only. With all the changes that had been adopted by the companies, and with all the orders or recommendations made by the authorities (which he did not at present say were not necessary for the safety of the public), railway companies would have to make up their minds to a considerable additional extent of line in the country. Then what would become of railway dividends? Men could not be expected to make new railways, except upon the expectation of a dividend; and if on the one hand dividends were diminished by increased expenses and diminished charges, the question was whether people would be in a position to go on making more railways, which would be rendered an absolute necessity by the changes now so largely introduced.

Mr. R. Price Williams said he had recently drawn attention to the rapid increase in railway traffic,[1] with a view of showing that the time was coming when, on some of the principal railways, the slow and the fast traffic must of necessity be separated, notwithstanding the advantages expected to be derived from the block system. He then exhibited some diagrams, illustrating what that

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxviii., p. 233.

increase had been, in the case of three of the principal railway companies, during a period extending over fourteen years (see also Plate 5). From those diagrams it was evident, that if for the future it was proportionate to the average during the previous fourteen years, the principal existing lines of railway in the country would be inadequate to provide for that increase. He produced at the same time a diagram of a working time-table of the Great Northern Railway Company, which fully bore out this position.[1] The Paper of the manager of the London and North-Western Company clearly showed how, by a thorough organisation and a well-trained staff, the enormous traffic of that railway was successfully and expeditiously managed, and the provisions being made by the relief lines likewise gave a clear indication that the chief officers of that railway were doing their best to make provision for the large increase of traffic that seemed inevitable. Already immense advantages had resulted from the relief lines. He thought it was rather to the absence of those relief lines on the Lancashire and Yorkshire railway, than to imperfections of the block system, that the state of things between Manchester and Bolton, described by Sir John Hawkshaw, was really due. He had resided for some years at Manchester, and could fully confirm the statement as to the complete block of traffic on that line, and he thought the Lancashire and Yorkshire Railway Company might well follow the example of the London and North-Western Company, and supplement that important throat of traffic between Bolton and Manchester with relief lines. He did not dispute the fact of the large capital expenditure which the construction of those relief lines and the provision of the block system must necessarily entail, but it was satisfactory to learn that the capital expenditure during the last five years on the railways of the United Kingdom had only increased 17 per cent., whereas the net revenue had increased at the rate of 37½ per cent. During the same period, which represented the time when these relief lines and other provisions for conducting the traffic had been made, the increase of capital on the London and North-Western amounted to 23 per cent., and of net receipts 20 per cent.; and on the Lancashire and Yorkshire railway the increase in capital had only been 10·39 per cent., and in the net revenue 10·29 per cent. The capital expenditure had, therefore, been judicious: it was, in fact, seed corn which would speedily fructify, and repay for the provision made for the large

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxviii., plate 32.

accession of traffic. It was doubtful whether, in view of the considerable capital expenditure which seemed inevitable, the reduction of fares was judicious.

No one, he thought, would question the conclusion to which Mr. Thornhill Harrison had arrived, that the policy of the Midland in running third-class carriages by all the trains was a wise, sound, and liberal policy. With a view of corroborating that conclusion he submitted a series of diagrams. Plate 5 showed, for the ten years from 1864 to 1874, the receipts from the first, second, and third-class passenger traffic, and also the number of passengers, on the London and North-Western, the Midland, the Great Western, and the Great Northern railways. It would be observed in the Great Western traffic diagram, that from the commencement of the period when the third-class passengers were conveyed by all trains, a large slice seemed to have been taken out both from the second-class receipts and the number of passengers, and appropriated by the third-class. Figs. 8, 9, 10, and 11 represented the receipts from, and the number of, first-class passengers on the four railways alluded to, and the outlines showed in detail the variations in the traffic. Referring to Fig. 8, it appeared that the number of first-class passengers by the London and North-Western railway in 1864 was 2,527,313, and the receipts £698,733. In 1868 the highest point in the number of the first-class passengers, and also receipts, was reached. From that date to 1874, it would be observed that there was a disturbed outline. In the latter year the number of passengers was 3,092,983, the receipts being £759,969. The average amount received per passenger in 1864 was 5*s.* 6¼*d.*, and in 1874, 4*s.* 11*d.* The outline in this, as in all the other diagrams representing the first class, showed very little variation. In the case of the Midland railway, Fig. 9, it would be observed that the outline was uniformly progressive, both as regarded the number of passengers and the receipts per annum, showing an increase of 52 per cent. in a period of ten years, while the receipts per passenger varied very little, only from 3*s.* 7¾*d.* to 3*s.* 9¼*d.* The Great Western railway, Fig. 10, showed, both with regard to the number of passengers and the receipts per annum, a very disturbed outline. The number of passengers varied from 2,243,092 in 1864, to 2,167,394 in 1873; the sum received per passenger being, in 1864, 3*s.* 8*d.*, as compared with 5*s.* 6¼*d.* on the London and North-Western. In the case of the diagram of the Great Northern first-class passengers and receipts, Fig. 11, there was also a perceptible increase; the sum taken per passenger in 1864 being 5*s.* 8¼*d.*, and in 1874,

5*s.* 5¾*d.* With regard to the London and North-Western second-class traffic, Fig. 12 represented a very remarkable outline. It would be observed that in 1864 the number of passengers was 7,580,641. This number increased in 1867 to the highest point reached, namely, 9,124,222. There was then a somewhat sudden fall in the next year, and a further rapid descent to 5,418,494 in 1873. It would, however, be noticed that there was a sudden rise in 1874, to which he would allude presently. The receipts per second-class passenger were 2*s.* 0¼*d.* in 1864, and 1*s.* 10*d.* in 1874. Fig. 13 gave an outline of the second-class traffic of the Midland railway. The maximum point as regarded the number of second-class passengers was attained in 1871, when the number was 3,815,187, which descended in 1873 to 2,477,719; but from that point there was, as in the case of the London and North-Western second-class traffic, a rise to 2,703,420 in 1874. It should, however, be observed that, although the numbers in 1874 had increased, the receipts had not, and the inference was unmistakable, and quite opposite to the conclusion arrived at by Mr. Thornhill Harrison, viz., that by retaining second-class carriages the other companies in the long journeys would have an advantage over the Midland; for it was evident that some of the short-journey third-class passengers had come back to the second class; the long-journey passengers willingly putting up with the inconvenience for the sake of the saving in the cost. Referring to Fig. 14, it appeared that the second-class traffic of the Great Western railway was in like manner subject to considerable fluctuations. From the highest point, in 1871, there was a sudden descent, from 6,866,894 to 5,065,416 in 1873. The receipts per second-class passenger varied from 2*s.* 1⅞*d.* in 1864 to 1*s.* 10⅝*d.* in 1874. In the case of the Great Northern, Fig. 15, the recovery in the number of second-class passengers in 1874 did not seem to have occurred. From 1871 there was a sudden and continued descent. From 1872 to 1874 there was still a slight descent both in the number of passengers and the receipts; the inference being that the great bulk of second-class passengers had found room in the third-class carriages and would there remain. Diagram 16 showed the number of third-class passengers, the receipts per annum, and the receipts per passenger during the same period on the London and North-Western railway. In this, as in all other cases, coincident with the alteration in the policy of the Midland, a very rapid rise had taken place in the number of third-class passengers and in the receipts therefrom. In 1864 the number of third-class passengers travelling by the London and North-Western railway

was 11,574,671. The number increased in 1871 to 21,879,064, and in 1874 to 34,245,380, being in ten years nearly 196 per cent. The receipts had enlarged from £672,571 in 1864 to £990,051 in 1871, and to £1,708,045 in 1874, nearly 154 per cent. in ten years, and in the last three years 72·52 per cent. The outline of the Midland third-class traffic, Fig. 17, showed a persistent, continued, and rapid increase in the number of passengers and in the receipts. The numbers as compared with the Great Western appeared relatively small, but the percentage of increase was very large. In 1864 the total number of passengers by the Midland was 7,659,321, which increased in 1874 to 20,316,246, showing a rise of 165 per cent. in ten years, and 54 per cent. in the last three years. The receipts in the same period rose from £361,566 in 1864 to £609,101 in 1871, and to £1,015,888 in 1874, showing an advance of 181 per cent. in the longer period. The outline of the third-class traffic of the Great-Western railway, Fig. 18, was remarkable. From 1868 to 1871 there was only a small increase in the traffic, but from that period to 1873 it was very large. In 1864 the number of passengers by this railway was 7,653,515; in 1871, 16,493,093, and in 1873, 25,395,341. The receipts in the same time rose from £465,002 in 1864 to £727,299 in 1871, and to £1,124,657 in 1873, being at the rate of 142 per cent. in ten years, and of 54 per cent. in the last three years. The Great Northern third-class traffic, Fig. 19, also indicated a remarkable development. The number of passengers in 1864 was 2,984,608, rising in 1871 to 6,032,265, and in 1874 to 10,351,474.

In regard to the reduction of fares, the chief point to determine was the actual cost of passenger traffic, and further to ascertain, separately, what the cost of each class of the passenger traffic amounted to. This, from the present method of keeping railway accounts, was not easy. He quite agreed that, as far as possible, the goods and passenger traffic working expenses should be kept separate, and he thought it was of great importance in the interest of the companies themselves that this information should be kept distinct in the half-yearly reports. Fortunately, in the case of the London and North-Western, the chief items of the goods and passenger traffic expenses were thus dealt with, affording within narrow limits the means of determining the relative expenditure in each department. From Table I., page 57, it would be seen, that the total income of the London and North-Western Railway Company in 1874 was £8,841,710, and the total expenditure £4,930,684, or about 56 per cent. of the receipts. The first item of expenditure was maintenance of way; in apportioning which

to the goods and passenger traffic he had adopted the ratio of train mileage. That was obviously a fair basis; if anything it rather favoured the goods, because the enormous tonnage carried over the line more than compensated for the speed of passenger trains. The same ratio was also fair in regard to the locomotive expenses, and there, again, the train mileage ratio favoured the goods traffic, inasmuch as the chief item of locomotive expenses was coal, the cost of which constituted more than one-third of the expense (see foot-note, page 57). The average consumption of coal for the goods engines was 45 lbs. per mile, while that of the passenger engines was scarcely 30 lbs. per mile. Of course the item of carriage repairs would be appropriated to passenger traffic, and, similarly, wagon repairs entirely to goods traffic; coaching expenses would, in the same way, be appropriated to passengers, and merchandise expenses to goods traffic. The item "Mileage of carriages and wagons of other companies" had been apportioned in the ratio of the train mileage, while for "General charges," "Law charges," "Parliamentary expenses," and "Rates and taxes," the ratio of the passenger and goods receipts had been adopted.

The ratios of train mileage were 47 per cent. for passengers and 53 per cent. for goods; while, in the case of receipts, the ratios were 42 per cent. and 58 per cent. On the average it appeared that about 45 per cent. of all the expenses were chargeable against passenger traffic, and 55 per cent. against goods. In the case of joint lines, the averages of 45 and 55 per cent. were, he thought, the proper ratios to adopt in the apportionment of these expenses. Steamboat expenses had been apportioned in the ratio of the passenger and goods receipts; canal expenses had been assigned to the goods. Having thus arrived at the proportion to be ascribed to passenger traffic, he had next to apportion that expenditure to the different classes of that traffic. He had been furnished by Mr. Findlay with the exact number of carriages, including bi-composites and tri-composites. The number of carriages on the London and North-Western was as follows: first-class two hundred and forty-three; second-class one hundred and forty-one; bi-composites five hundred and eighty-four; tri-composites seven hundred and sixty-three. Two-thirds of the latter, the proportion due to the first and second-class traffic, gave fourteen hundred and seventy-seven as the total number of first and second-class carriages, as compared with twelve hundred and ninety-eight third-class carriages, including the one-third of the tri-composites. The number of first and second-class passengers in the year 1874 was about nine millions; equivalent to six thousand two hundred and

fifty-six passengers per carriage per annum; while the number of third-class passengers was thirty-four millions, or twenty-six thousand three hundred and eighty-three passengers per carriage per annum. The gross receipts for passenger traffic, including mails, amounted to £3,672,208, the total working expenses being £2,204,040. The gross receipts (excluding mails) were, however, £3,029,769, and the passenger traffic expenses, after deducting the share due to mails, amounted to £1,818,451. The proportion, therefore, of these expenses charged against the first and second-class traffic in the ratio of the number of first and second-class carriages (viz., 53 per cent.) amounted to £967,871, or 73 per cent. of the receipts, leaving £353,850 as the net receipts. The gross receipts from first and second-class traffic amounted to 1*s*. 9¾*d*. per train mile, while the net receipts were only 5¾*d*. per train mile. Similarly, the gross receipts per first and second-class passenger were 2*s*. 10¼*d*., while the net receipts were only 9¼*d*. Apportioning the passenger traffic expenses as before in the ratio of the number of the third-class carriages, he found that the working expenses amounted to £850,580, leaving a net sum of £857,465. In other words, the gross receipts were 2*s*. 4½*d*., and the net receipts 1*s*. 2¼*d*. per train mile, while the gross receipts per passenger were exactly 1*s*. and the net receipts 6*d*.

Since the third-class traffic yielded so large a return as 50 per cent. of net profit, while the first and second class only gave 26 per cent., he thought railway managers would, when the proper time arrived, be prepared to offer still more substantial concessions to the third-class passengers, and that they would find that the resulting increase in the traffic would be proportionately large and remunerative. The results of the above calculations were given in Tables I. and II.

TABLE I.—LONDON and NORTH-WESTERN RAILWAY WORKING EXPENSES, 1874.
PASSENGER and GOODS TRAFFIC.

Ratios used in Apportionment.	Total.	Passengers.	Goods.
	£.	£.	£.
Receipts	8,841,710	3,672,208	5,169,502
Ratio	(100)	(41·7)	(58·3)
Train miles	30,474,401	14,462,293	16,012,108
Ratio	(100)	(47·4)	(52·6)

—	Proportioned in Ratio of	Total Expenses.	Per Cent.	Proportion to Passengers.	Per Cent.	Proportion to Goods.
		£.		£.		£.
Maintenance of way	Train miles	1,020,963	47·4	483,936	52·6	537,027
Locomotive power	Train miles	[1]1,318,374	47·4	624,909	52·6	693,465
Carriage repairs	..	144,844	..	144,844	..	..
Wagons	..	161,001	..	..	..	161,001
Traffic expenses—coaching	..	555,467	..	555,467	..	..
Traffic expenses — merchandise	..	940,109	..	..	..	940,109
Mileage of carriages and wagons of other companies	Train miles	26,029	47·4	12,338	52·6	13,691
General charges	Receipts	162,361	41·7	67,705	58·3	94,656
Law charges	"	32,031	41·7	13,357	58·3	18,674
Parliamentary expenses	"	37,000	41·7	15,429	58·3	21,571
Compensation to passengers	..	62,026	..	62,026	..	..
Compensation for goods	..	60,075	..	..	..	60,075
Rates and taxes	Receipts	153,397	41·7	63,966	58·3	89,431
Government duty (passenger)	..	94,295	..	94,295	..	..
		4,767,972	..	2,133,272	..	2,629,700
Average ratio	..	(100)	..	(44·85)	..	(55·15)
Proportion of expenses (joint lines)	In above average ratio	86,061	44·85	38,598	55·15	47,463
Steamboat expenses	Receipts	65,156	41·7	27,170	58·3	37,986
Canal expenses	..	11,495	..	..	..	11,495
Total	..	4,930,684	..	2,204,040	..	2,726,644
Ratio	..	(100)	..	(44·7)	..	(55·3)
Percentage on receipts	..	55·8	..	60·0	..	52·7

	£.
[1] Coal	441,201
Wages	384,427
Repairs	392,842
Salaries of Staff, etc.	99,904
	£1,318,374

TABLE II.—LONDON and NORTH-WESTERN RAILWAY. ANALYSIS of PASSENGER TRAFFIC, 1874.

—	Number of Carriages.		Number of Passengers.	Passengers per Carriage per Annum.
				Number.
First and second class—				
First class	243			
Second class	141			
Composites.	584	Per Cent.		
Proportion of tri-compos (⅔ of 763) .	509	(53·225) 1,477	9,239,933	6,256
Third class.	1,044			
Proportion of tri-compos (⅓ of 763) .	254	(46·775) 1,298	34,245,380	26,383
Total number . .	..	2,775	43,485,313	..

Passenger train miles, 1874 = 14,462,293.

RECEIPTS and EXPENSES per TRAIN MILE and per PASSENGER.

—	Gross Receipts.	Working Expenses.	Net Receipts.
	£. Per Cent.	£. Per Cent.	£. Per Cent.
Total passenger traffic, including mails, &c..	(100) 3,672,208	(60) 2,204,040	(40) 1,468,168
Deduct receipts for mails, &c..	(100) 642,439	(60) [1] 385,589	(40) 256,850
Total passenger traffic, excluding mails, &c. . .	3,029,769	1,818,451	1,211,318

—	—	—	—	Per Cent. of Gross Receipts.	Per Train Mile. s.	Per Train Mile. d.	Per Passenger. s.	Per Passenger. d.
First and second-class traffic—	£.	£.	£.		s.	d.	s.	d.
Gross receipts	1,321,724	..	..	..	1	9¾	2	10¼
Working expenses[2] (53·225 per cent. of £1,818,451)	..	967,871	..	73·2	1	4	2	1
Net receipts	..	..	353,853	26·8	0	5¾	0	9¼
Third-class traffic—								
Gross receipts	1,708,045	..	..	..	2	4½	1	0
Working expenses[2] (46·775 per cent. of £1,818,451)	..	850,580	..	49·8	1	2¼	0	6
Net receipts	..	..	857,465	50·2	1	2¼	0	6
Total first, second and third class traffic—								
Gross receipts	3,029,769	..	..	..	4	2¼	1	4¾
Working expenses[2] . .	..	1,818,451	..	60·0	2	6¼	0	10
Net receipts	..	..	1,211,318	40·0	1	8	0	6¾

[1] *Mails, &c.*—Working expenses taken in the ratio of the total expenses to total receipts, viz., 60 per cent.

[2] The working expenses are apportioned to the different classes of traffic in the ratio of the number of carriages of each class.

Col. MARTINDALE thought it might interest the members to hear the views of one of the general public, to whom, however, by force of circumstances, railway management had been a subject of more than usual attention. It had been said that the block system was necessarily very costly, that it involved delay and unpunctuality, and that by a judicious use of the permissive system these evils might be removed, while sufficient safety was insured to the public. It had also been said, that if the block system were persisted in, and if the traffic continued to increase in the same proportion as during the last ten years, it would be absolutely necessary to create additional lines, for which it was not easy to see whence the dividends were to come, and therefore how the capital was to be raised. Those statements were based on the remark that the block system was forced on the railways by the general public. As one of that body he ventured to say that the general public did not really care about the block system. They had been taught to believe that the maximum of safety was derivable from it, and on that account they advocated it; but if the great railway managers (whose invaluable responsibilities, ability, and solicitude all would acknowledge) would show that there was any other method by which, without the evils and the expense of the block system, sufficient safety could be secured—then, as far as the public were concerned, there was an end of that system. The question of the additional lines, which it was said must, under any circumstances, be constructed between the leading centres of commerce, was an additional reason for endeavouring to settle as rapidly as possible this vexed question. For it would be worse than idle to establish the system at a great cost, and with great difficulty to train men to work it, if a simpler system would suffice. As to rates and fares, experience seemed to show that it was not possible to draw a hard-and-fast line. The question must depend on the character, the resources, and the population of the country through which a line passed. Some years ago he had the opportunity of testing the matter in the simplest form in New South Wales, when he was Sole Commissioner of Railways. The Government both made and worked the lines; they were short, and the population was sparse. The expenses were nearly double those in England; but great pressure was brought to bear upon the Government to reduce the fares to a point as low as the English rates, if not a trifle lower, it being urged that the increased traffic would more than recoup any loss from a reduction of rates. The reduction was fairly tried, and the result was, that the receipts barely sufficed to pay the

working expenses. With great difficulty, and at the cost of much unpopularity, the Government raised the fares to at least their previous amount, and then the receipts increased in proportion. But here the experiment was weighted by competition of the most active character; and this led him to consider the question of additional lines in connection with reduced rates. The need for those additional lines arose from the greater number of trains, some fast and some slow. But was it a necessity to run all those trains? This was the pith of the question. While railway managers had come to agreements in regard to rates and fares, they had apparently not done so in regard to the number of trains to be run. If, by an agreement among themselves, they could diminish the number, and yet provide sufficient to accommodate the public, the same necessity for the additional lines would no longer exist, except perhaps between the great centres, and net receipts would be proportionately increased. It was notorious that at present the numbers travelling in first and second-class carriages were very small. That pointed to the desirability of reducing the length of the trains, as the Midland Company had done, and still more to the importance of united action among railway managers, in order to reduce the number of trains. It was obviously a fallacy to compute receipts by the train-mileage. The number of passengers and tons of goods carried per mile formed a much more solid basis of calculation, as was well pointed out in the "Economist," of the 7th of November, 1874. He did not think the Pullman car as comfortable as the ordinary first-class carriage, in which all the sleeping accommodation required for the short journeys of this country could be provided. But, though not a *bon vivant*, and especially not on a railway journey, he thought a restaurant carriage might with advantage be attached to some trains, in order to prevent the hurried rush into the refreshment rooms. In conclusion, he begged to submit that competition conducted by increase of trains run and consequent increase of working expenses meant increased expenditure; competition conducted by reduced trains run might even with reduced rates mean increased dividends.

Mr. Allport said he was exceedingly disappointed with Mr. Findlay's Paper, which was not an exposition of railway management, and might have been better entitled "Statistics of the London and North-Western Railway." The subject of railway management was of much vaster dimensions than anything attempted in that communication, which appeared to have been used by several speakers as a basis on which to found an attack upon the Midland Company; he would therefore mainly confine his

attention to the changes introduced by that company. He should be sorry if the Paper went forth as an exposition of railway management, on the higher branches of which it scarcely touched. The subject of railway sidings and the manipulation of trains was a very fit one for discussion, and he might be permitted to give a few particulars of a set of sidings, about 17 miles long, and covering about 50 acres of ground, on the Midland railway, at Chaddesden, near Derby (Plate 6), through which were passed in 1873 the large number of one million and eighteen thousand wagons, or three thousand two hundred per working day, and in one month ninety-six thousand wagons had passed. They were similar to those at Shildon, and the receiving sidings would hold about one thousand wagons, and the marshalling sidings upwards of three thousand, and five trains could be marshalled and sorted at the same time. There were ten receiving sidings, converging into one neck, from which thirty-five sidings branched off. Through these eleven trains had been passed per hour, averaging from thirty-five to forty wagons each. He had timed the shunting, and found that it varied from three and a half minutes to four and a half minutes per train. When a train arrived at one of the ten receiving sidings, the engine immediately ran forward, and a shunting engine went to the back of the train to push it towards the neck. Horses were in readiness to take each wagon forward, the man calling out to the pointsman which siding it was destined for. At Chaddesden there were about ninety horses and six shunting engines. While the engines were taking coke and water the trains could be marshalled. These sidings accommodated traffic from six different directions, from the North, from Manchester, from Nottingham, from Birmingham, from London, from the North Staffordshire district, and from one or two small branches. The traffic was both goods and minerals, the greater part being goods traffic. The short sidings were for spare wagons that might have to remain on hand for a time. The sidings at Toton (Plate 6) were about 14 miles long, and were entirely for minerals. The two centre lines were the main passenger lines, and the goods and mineral lines extended some considerable distance on either side, practically giving four lines of rails through. The operation of sorting into distinct sidings the wagons belonging to colliery owners, of which there were a great number, was exceedingly simple and interesting. The work was done very quickly. A better plan might possibly be introduced; but at present he failed to see that any improvement had been suggested. The gridiron system was untried; but he hoped it would

succeed. The idea, however, of passing from three thousand to four thousand wagons through that system would appear to practical railway men an absurdity and an impossibility, especially when, as it was proposed to construct steep gradients, every wagon would have to be stopped in a particular position by break-power, and since it would require several pointsmen, and probably a breaksman to each siding. If it succeeded, he should be one of the first to recommend its adoption.[1]

Credit had been given by Mr. J. Thornhill Harrison to the Midland Company for introducing third-class carriages with all trains; but while it was acknowledged that the alteration had been a success, he doubted the propriety of the change. Mr. Allport however believed that it was in the interest of the public and of the companies that the change should be adopted. Reference had been made in the course of the discussion, and also in the public press, to the extraordinary stagnation in first-class traffic. For some years it was a source of anxiety to himself and his directors how to fill the carriages. It was found that by running (as they were compelled to do by the competition with other companies) separate carriages to almost every town, the trains were very long, and the passengers few in number; and in order to carry third-class passengers to the same districts it was necessary to duplicate the trains. The Midland directors then determined to put on third-class carriages to all the trains. The result was a most remarkable improvement in the receipts and

[1] The cost, for the year ending December 1874, of working the Toton and Chaddesden sorting depôts. The amount includes shunting power, calculated at 5*s.* per hour, and the provision for depreciation of horse stock:—

TOTON.

	£.	*s.*	*d.*
Staff	6,790	16	8
Clothing	451	0	0
Horses	4,473	17	6
Shunting engines. . . .	8,357	0	0
	£20,072	14	2

CHADDESDEN.

	£.	*s.*	*d.*
Staff	9,326	8	0
Clothing	334	9	5
Horses	4,547	15	9
Shunting engines. . . .	13,371	0	0
	£27,579	13	2

in the number of passengers carried. It was also found that the duplicate trains were not needed, and the expenses, instead of being increased, were actually diminished by half a million miles per annum, by taking off the unnecessary trains. That resulted in a curious circumstance. The second-class passengers were largely diminished, by what the higher classes of society might term the objectionable element being removed into the third class. The passengers remaining in the second class were chiefly professional men belonging to the army and navy, clergymen, solicitors and others, and even persons of a higher class who preferred economy to comfort. In 1873 the first-class carriages only averaged between four and five persons per train per mile, and the number of second-class passengers between five and six. In other words the first-class passengers yielded 7·64*d.* per mile, the second class 6·96*d.*; while for the third class there was an average of thirty-two passengers per mile, yielding 2*s.* 8*d.* It was evident, therefore, that if the travellers by the first and second classes were all put into the first class the carriages would not be half full. It was considered undesirable to increase the payment by the second-class passenger, consequently the first-class fare was reduced to the second-class scale. The result was the second-class passengers had gone into the first class, and up to the present time there had been very few complaints of inconvenience or annoyance experienced by first-class passengers. He hoped that in the course of a year, when the alteration had had a fair trial, it would commend itself to the favourable consideration of other railway companies. He was aware that the President of the Institution and other railway men were much opposed to it. In England such radical changes were against the wishes and opinions of a particular class of the community; but looking at the stationary condition of the first and second classes for many years past, and at the enormous increase in the third-class receipts since 1872, he thought the recent change was a step in the right direction. It would diminish the weight of the trains and increase the number of passengers, and he believed that financially it would prove a success; of course, in case of failure the Midland Company could easily revert to the former system, and would alone incur the odium and the expense: if the plan succeeded, other companies could avail themselves of it. If Sir John Hawkshaw, who was a pioneer of railways, had read up railway statistics, he must have come to the conclusion that the vast increase in receipts had been caused by reduction in prices. He would cite the experience of the Midland railway eighteen or twenty years ago.

That company had express, first-class, second-class, third-class, and fourth-class or Government fares. The express fare was 3*d.* a mile, first-class $2\frac{1}{2}d.$, second-class nearly 2*d.*, third-class about $1\frac{1}{4}d.$, and the Government or fourth-class 1*d.* Soon after Mr. Allport took the management of the Midland, his attention was directed to those fares, and he thought it advisable to simplify them. He therefore recommended the directors to reduce the express fares. That appeared to involve a loss of revenue, amounting to £40,000 or £50,000 a year; but the express fares were abolished, and in the first year there was a gain instead of a loss. He then thought it advisable to reduce the first-class fares from $2\frac{1}{2}d.$ to 2*d.*, which involved apparently a much larger sacrifice of revenue. Instead of adopting the plan generally the line was taken in sections; but in every instance the result was beneficial. On the last section the loss appeared upon paper to be from £30,000 to £35,000 a year; but there again it turned out to be a gain. The rates of the three classes were then reduced to 2*d.*, $1\frac{1}{2}d.$, and 1*d.* per mile. Again, the third-class arrangements resulted in a large profit to the company, amounting to about £183,000 increase in the receipts (equal to 9*d.* per train mile), and 500,000 miles reduction in train mileage. Before the recent change the receipts from first-class passengers were £228,000 per annum, second-class, £208,000, third-class, £961,000. Taking those figures into consideration, he thought the Midland Company were justified in trying the experiment of putting the first and second classes into one, which, as far as he could at present judge, would result in no loss of revenue and in no annoyance to passengers, but in economy in working, lightening of the trains, and greater punctuality. He exhibited an interesting and curious document—the working time-table of the North Midland railway between Leeds and Derby, for January 1843. It was contained in two pages, one for the up trains and the other for the down. There were then two lines of rails between Derby and Leeds, as at present, and the number of trains was thirteen in each direction, including two through goods trains, one goods train over a portion of the railway, three mineral trains running 20 miles, and six passenger trains. In 1875, instead of twenty-six trains daily, there were three hundred and twenty-one trains. If two lines of rail were capable of accommodating such an increase, he did not think that railway companies or the English public should hesitate, if the traffic still continued to enlarge, in expending the necessary capital to provide additional accommodation. He should be sorry for an opinion to prevail among railway men and engineers, that

the limit of the net receipts had been attained. He believed that companies would spend capital to provide for an accession of traffic; and he saw no reason why the three hundred and twenty-one trains of the Midland, to which he had alluded, should not be double that number in a few years, and why a similar augmentation should not take place elsewhere. If the traffic increased, the needful accommodation should be provided. As an example of the growth of traffic upon the London and North-Western railway, it was stated that between Rugby and London, deducting the suburban traffic, there were sixty-four down trains and sixty-three up trains—one hundred and twenty-seven in both directions. To accommodate that number the London and North-Western Company, having one of the best lines for gradients in England, had for many years past a third line, and between Bletchley and London a fourth line, and they were now piercing Primrose Hill by a second tunnel, which would practically give four lines throughout the greater part of the distance. They were in Parliament also this session, to obtain power to duplicate the line from Bletchley to Rugby, which would give additional facilities. All this was done to provide for one hundred and twenty-seven trains per day. On the Midland, eliminating suburban and short trains, there were at the present time, between Wigston and London, one hundred and seventy-four trains per day, and that on a line with less easy gradients than the London and North-Western. This showed what could be done upon two lines for a distance of nearly 100 miles. Surely there ought to be no doubt about finding capital if the traffic should still increase 100 per cent., or even 200 per cent. He was persuaded that, if the prosperity of the country continued, the time was not far distant when the lines would have to be doubled; and he saw no reason to doubt that those additional lines would pay. Upon another part of the Midland main line there were no fewer than two hundred and forty-nine trains per day. The statistics which had been given respecting the London and North-Western Company, were such as could be obtained from the Blue-books annually presented to Parliament by the Board of Trade. He would therefore only allude to the six questions propounded by Mr. Findlay. He should have been glad to have had the opinion of the London and North-Western Company upon them; but failing that, would venture to answer the questions himself. With respect to the first, he sincerely hoped no company would ever adopt facing points at refuge sidings. It had been the aim of the Midland Company to do away with them wherever it was possible. Whatever system

was adopted, they were fraught with danger. Even when the locking apparatus or the locking bar was introduced, there was a liability to accident which railway managers should avoid. He did not quite understand the second question. Assuming A, B, and C to be three block stations, was it meant that no train should be allowed to leave A before the preceding train had passed on towards C? or that it should not be allowed to leave A until the preceding train had passed the distance-signal at B, and was under the protection of the home-signal at B? He would take both suppositions. In his judgment, a line with heavy traffic like the London and North-Western, or many of the larger companies, could not be worked if the trains were blocked back to A until the previous trains had reached the block at C. That would be impracticable, unless the blocks were so close as to render the expense and difficulty of working very great. He thought no company should allow a train to leave A until the preceding train had passed the distance-signal and reached the home-signal at B. On this point his company was at variance with the officers of the Board of Trade, who thought that no train ought to be allowed to leave A until the preceding train had cleared the home-signal at B, and was proceeding on its journey towards C. The Midland Company argued that the distance-signal ought to be an ample protection to trains standing at the home-signal at B. If the distance-signal was at danger, the engine-driver should have his train so much under control that he could pull up outside that signal and gradually draw under its protection, although the previous train might be under the protection of the home-signal at B. The answer to the third question would depend very much upon the nature of the traffic and the closeness of the block-signal. It was the custom on the Midland, when a passenger or express goods train arrived at A, to send the signal to B, and B forwarded it to C, although the "train on line" signal might not have been received by B from A. That was a matter of working which altogether depended upon the nature and extent of the traffic. He considered it advisable to call the attention of the forward station by the "be ready" signal, and in the case of express and important trains the signal might be sent even still farther on the line, so as to show the position of the train, and when it might be expected to arrive at the various block-stations. He quite favoured the view that the safest and best way of working steep inclines was by a second engine in the rear. As Mr. Webb explained, the Shap incline had been worked on that system for many years without an accident, and in like manner the Midland

railway had worked the Lickey incline, 1 in 37, by an engine in the rear, and he did not remember any accident ever occurring. The Board of Trade officers maintained that no engine ought to be allowed to assist in the rear; and some went still further, and stated that no train ought to have two engines at all. He could not see how it would be possible to work the traffic of the country with satisfaction to the public, and with punctuality, without assistant engines. It might be desirable in some cases to put them in front, but in other cases it was best to have one in front and one in the rear. Perhaps the best precaution against a goods train running backwards when ascending a steep incline, if the nature of the traffic permitted, was to have safety-points, which would turn the wagons off the line. In other cases he had no doubt that arrangements could be made by which the wagons could be allowed to run on the line, and then be turned by points and crossings on to the proper line or into sidings. On a steep incline there might be catch-points running into a siding with a steep ascent, upon entering which the velocity of the wagons would be diminished, and they would ultimately come to a stand. No one, however, could answer such a question dogmatically. Different systems were required to meet the varying circumstances of each case. It was certainly not desirable, looking to the enormous increase of traffic on the principal railways, to reduce the velocity of trains. The larger the traffic, the greater ought to be the speed, within reasonable bounds. The more the pace was reduced, the less available the line became. Where the line was worked under the block system, it must be evident that if the rate were reduced from 50 miles to 40 miles an hour, longer time would be occupied in going from station to station, and delays would necessarily arise. He did not advocate excessive speed. Railway companies had perhaps exceeded the limit, not of speed, but of economy. He did not think that passengers liked very high velocities, and it was certainly more economical to a railway company to maintain a moderate speed. He was not able to state the ratio of the weight of the train on the Midland under the former system and under the present; but the abolition of the second-class carriages had necessarily diminished the weight considerably. With regard to what were termed fancy carriages, he might be allowed to state his own experience. He had travelled 20,000 miles in America in the Pullman carriages, and he was so much struck with their great ease in running on bad lines, and the great comfort they afforded, that he induced the Midland Board to give them a trial. They had been used for nearly twelve months

between Bradford, Leeds, and London, and they were so well filled that frequently room could not be found for applicants. It was the intention of the company to extend the use of those carriages. He believed the principle of their construction was a right one, and in his judgment they were the best and the most comfortable carriages ever introduced upon railways. Travelling with his daughter and son-in-law, he left San Francisco at 7 o'clock on Tuesday morning, and reached Chicago on Sunday evening, when they felt that it would be no annoyance, or fatigue, or inconvenience, after taking some refreshment, to go back to the station and return to San Francisco. The people of this country now had an opportunity of trying these carriages, and the more they tried them the more they would like them.

Mr. JOHN DIXON quite agreed that a paper on regimental discipline could hardly be dignified by the title of an article on the art of war; but he did not admit that the Midland railway had been the pioneers of increased facilities to the public. Many years ago the North-Eastern railway commenced the development of the passenger traffic and the reduction of fares which had led to such wonderful progress both in their passenger, goods and mineral traffic. It should never be forgotten that railways were made for the public, and not the public for railways. No step forward in railway management, no increased facility given to the public, could ever be final. Whatever was done could only be an advance towards further requirements and further advantages. One subject, however, had not been sufficiently dwelt upon, namely, the gross want of punctuality which prevailed in the management of railways. The whole object of the Papers had been to point out the benefit which system, order, and regularity could secure; but the gross departure from system, order, and regularity manifested in the utter want of punctuality underlay nearly all the evils of railway management. It was this which caused the difficulty in the conduct of quick and express traffic in conjunction with the ordinary traffic, and which was the origin of the majority of accidents. How would the business of the city of London proceed if there were such an utter disregard to appointments as was shown by the great railway companies? It had been said that punctuality could not be obtained; but he was of opinion that it could be and ought to be. He was convinced that when legislation enabled the public to proceed by civil action against railway companies for publishing time-tables which they habitually disregarded, and threw on the railway company the onus of proof that the delay was reasonably unavoidable, railway managers

would find it easy to observe punctuality. Although a small increase in the staff might be necessary at first, it would in the end be found possible, either by the employment of travelling porters or in some other way, to reduce the number, and thus effect that economy which system and order produced.

Mr. Bramwell said, although Mr. Dixon professed to represent the interest of the public, he, as one of the public, did not agree with the views which had been expressed on the question of punctuality. There was one way of getting it; and that was by diminishing the pace to that of the Continent, or a maximum of only 75 per cent. of the present rate of speed. If by ill-luck the Government ever acquired the railways, he had no doubt but what punctuality would be thus secured, and then, as now in France, there would be stoppages to make up time, five minutes at every station nine days out of ten, in order that on the tenth the train might not be late. Men of business, however, in England could not afford to waste time; and he was certain the majority of the travelling public did not wish to buy punctuality at so great a cost. As a test of this, suppose a time-table were published with two sets of columns, headed respectively "Slow and punctual trains," and "Express trains not guaranteed to arrive with exact punctuality," which class would be generally adopted? No one would ever think of taking the slow train. Why therefore should this bugbear of punctuality be enforced when there was no other way of obtaining it but by running slow trains? He did not say that railway companies, having published time-tables, should not do their best to keep the time, for it was their duty to do so; but to ask for absolute punctuality was to his mind a monstrous thing, as it could not be got without a sacrifice of the time of the public. He went to Scotland the other day, and the train was twenty minutes late in starting from Carlisle, where he had slept. The delay was caused by a heavy gale which the train had encountered in coming from the south: but was it worth while to detain the train twenty minutes every calm night of the year in order that it might be punctual on those few nights when there was a storm? There was one expression in Mr. Findlay's Paper which, if he remembered it aright, alarmed him. It was said that railway managers in this country did not have the facilities that railway managers on the Continent had. Mr. Bramwell had feared this meant that it was an advantage to box the public up in a waiting-room and not let them out until five minutes before the train started, when there was a rush on to the platform and the strongest and least gentlemanly

man secured the best seat, although he might have come last to the station. Repeated observation caused him to believe that such a system was not an advantage; on the contrary, he felt confident the advantage must lie with the quiet filling of the train. In conversation, however, Mr. Findlay had told him he had not meant, by the statement alluded to in the Paper, to express a desire for the shutting-up of passengers in waiting-rooms, but he intended to refer to the fact that English companies were compelled to take passengers up to the last moment, whereas on the Continent they were not taken after five minutes before the time of starting the train as announced on the time-tables. But that which a passenger wanted to know was not so much when the train started as when he would be received with a reasonable amount of baggage and be able to get seated. Everybody could understand that a reasonable interval must elapse between the time when they could be received at the station, and the moment of starting. Letters occasionally appeared in the papers—generally from persons who seemed to have nothing else to do—stating, "I went down to a station on such a day and saw the train three minutes late in starting." If such an objector, being a passenger, had gone down just at the very moment the train was starting and had been hustled into a carriage, he would have said, "I was in time for the train, but was not suffered to take my seat tranquilly and quietly." Then it was stated that punctuality was necessary for safety. He did not mean to say it would not be an adjunct in obtaining safety; but surely the way in which railways were conducted at the present time did not leave safety to depend upon trains being punctual all the way, and punctual at every little roadside station. With respect to another subject, Mr. Rapier had said in a somewhat jaunty manner, "If there is no room, let the passengers stop behind. That was done in the days of the old stage coaches. If 'The Wonder' when it came up had no room, the passenger had to wait until 'The Telegraph' arrived, or until the next day"; but Mr. Rapier forgot that as soon as there were more passengers than one stage coach could accommodate, there came an opposition, and that no one would have dreamed of or would have tolerated the interference of Parliament to prevent such an opposition. Railways, however, had a monopoly which was not granted to any other companies, except perhaps gas and water companies. If a man embarked £200,000 or £300,000 in a boat to New York, and went on until it paid, another boat was started, and Parliament did not interfere with the trade; but if a company embarked £2,000,000 or £3,000,000 in a railway, Parliament gave a monopoly,

and if a company enjoyed the monopoly they must also have the responsibility which attached to it, and must provide accommodation for all who wished to be accommodated.

He had been much struck by the ingenious mode of sorting trains on the gridirons. The diagrams (Plate 2) reminded him of some of the new kinds of composing machines for setting up type, which picked out the letters from the various boxes one by one and put them into sentences.

There was one other thing to which he wished to allude. Mr. Webb, in explaining the powerful breaks now employed on the express trains of the London and North-Western, said they were not used at every station, but simply once on the journey to see that all was right, and that the trains, as a rule, were stopped by the ordinary breaks. That was an extremely wise precaution, because, on the one hand, it prevented the accidents which might arise from carrying on too long in reliance on powerful breaks, which might, however, fail when they were most needed; while, on the other hand, it supplied the best evidence that the breaks were in proper order if wanted for an emergency. It seemed to be a happy medium between continually using such powerful breaks and never using them at all.

One gentlemen who used to attend the meetings was very fond of this witticism: "I have inventors coming to me, and saying 'I have a break that will stop a train dead;' but my reply is, 'If you have a break that will stop the train dead, you have a break that will kill the passengers.'" That, however, was only a figure of speech, for he had never yet seen a break that could arrest a train in a manner to cause injury to the passengers. He believed the best breaks were only capable of reducing the speed of the train at the rate of 2 miles in every second. It must be recollected that gravity would put into a falling body a pace of more than 20 miles an hour in each second of time, and would do this without causing injury. Now this pace of 20 miles an hour was arrived at by equal increments in equal times, and thus the effect of each increment on the human frame could be readily tested, for a fall through 4 feet, or even through 1 foot, subjected the person making it to precisely the same increments of speed as would be given by a fall through 16 feet, or through any greater distance, and yet no harm was caused by a fall through 1 foot, or even through 4 feet. An ordinary swing, if describing nearly a semicircle, was another instance of the large increments of motion which, in a given time, might be communicated to, or might be abstracted from, the human body without injury. It seemed to him, therefore, that there was

room for improvement without fear of killing the passengers by the excellency of the break. For the fifth time he desired to protest against the way in which breaks were commonly made. One thing in their manufacture was simply abominable. He alluded to the ordinary carriage break, with which it was impossible for one block to form the abutment of the other. An old wagon-break where the block of wheel 1 formed the abutment of wheel 2, was an infinitely better thing than that on which so much money was now spent. It was said that the blocks soon wore themselves right by contact; but that was precisely the thing they did not do, because as soon as the prominent block came into hard contact with the wheel and stopped it, there was no further motion between the wheel and the block, and therefore the block did not wear, while the block which had not stopped its wheel did wear under the rubbing action. He had made it his business for the last ten years to watch trains drawing up at platforms, and if there were only two pairs of wheels to be broken under a tender, in ninety cases out of a hundred, one pair was running.

Mr. Grover said the first railway carriages were formed on the model of the stage coaches, and the wheels were very near together, but at the same time the curves of the lines were very large. A radius of ½ mile was considered quite as small as was admissible; but by degrees the carriages had grown longer and longer, while the curves were becoming smaller and smaller. At the present time a curve with a radius of 10 chains was considered a very good one, and there were some railways on the Continent where the curves on the main line had only a radius of 6 chains or even less. If, then, the curves were being reduced while the base of the wheel was being increased, it was manifest that railways were progressing towards an error, and that something ought to be done to remedy it. Had the originators of railways been obliged to deal with such curves as were now employed, he thought they would not have built the coaches as at present. The American system of eight-wheel coaches to a certain extent remedied that inconvenience, but for general English traffic he did not think that system would be useful, as the vehicle was long and unwieldy. True it afforded the most perfect flexibility, but considerable difficulty was experienced in putting in the side doors. The frames were apt to sag, and then the doors jammed. The real want was a four-wheel coach, which should have the power of going round a curve, and yet should not depart from the standard type of vehicle now in use. He had for the last five years been endeavouring to introduce a vehicle built so much like the ordinary

English coach that the difference could hardly be noticed, with the bogie system applied to it. He placed the axles at each end in bogies to work with cross bars, in such a way that when the wheel struck the curve each axle did its work, and there was no grinding or friction. It combined the advantages of the ordinary four-wheeled vehicle with those of the bogie system. It was extraordinary that a pivoting arrangement of the front axle should be considered necessary in ordinary vehicles, for going round corners, while nothing of the kind was used for railway rolling stock. While getting rid of the various shocks to which vehicles were exposed in traversing curves by this contrivance, he at the same time reduced the great weight of the under-frames, which was so formidable an objection to the present system. He believed there could be no substantial reduction in the weight of the vehicle until the shocks and strains which necessitated the great strength of the under-frame could be obviated.

Mr. Barlow, Vice-President, desired to direct attention to the extraordinary increase in the expense of maintenance of way during the last few years—an increase of expense which he did not think could be explained by additional wages or price of materials. For the five years from 1864 to 1869 the cost of locomotive power, with which he compared that of the permanent way, averaged 8·43*d.* per mile per annum. In making this comparison he had taken four large lines of railway, the London and North-Western, the Midland, the Great Northern, and the North-Eastern. He had omitted the Great Western because from the recent change of gauge of that line, it was difficult to follow the expenditure. In 1864 the cost per train mile for locomotive power was a little under 8½*d.*, and the cost of permanent way, including renewal, was 5*d*; in 1869 the cost of locomotive power was the same, 8½*d.*, and the cost of the permanent way 5½*d.*; but during the last half-year the cost per mile of the locomotive power was 10½*d.*, and the cost of the maintenance of way 8*d.* per train mile. He had taken the train mile as a measure because it appeared to him to be a more accurate standard than anything else, for it represented the work of the railway itself. While there had been an increase of only 25 per cent. in the locomotive power, which might probably be put down to the enhanced cost of labour and materials, there had been an increase of 61 per cent. in the charge for maintenance of permanent way, for which it was difficult to account. No doubt there were several causes tending to produce it. The stations were now much larger, but one would imagine that the larger stations were the result of a greater amount

of traffic and of mileage run. Another cause probably was the changing from iron to steel rails; and something might be attributed to the mode of keeping the accounts. There might now be a higher conscientiousness in the mode of account-keeping, so that expenses formerly charged to capital were now charged to revenue. Comparing the present with a period long past, that would no doubt have a great deal to do with it; but 1869 was too recent for such an explanation to be accepted. The accounts of 1869 and the accounts of the present year were probably equally correct as regarded that point; it was therefore exceedingly difficult to explain how this great increase in the cost of maintenance of permanent way arose. The subject demanded the attention of all who had the management of railways. In reality it amounted to a reduction of the dividend to the extent of 1½ per cent. The total free capital of the four railways before mentioned, irrespective of borrowed money and of preference shares, amounted to £76,000,000, and the average dividend upon the whole of that amount had been for the last half-year 7½ per cent. The train mileage during the same period was 43,000,000; which showed, first, that the money available for dividend amounted to 16*d.* per train mile, and, next, that a receipt of 2*d.* per train mile produced a dividend of 1 per cent.; so that the increased cost of the permanent way alone amounted to 1½ per cent.

Mr. J. W. Barry suggested that the train mileage was not the proper element for the comparison of the cost of maintaining the permanent way. The weight of trains had continually increased of late years, and it would be seen, from Plate 1, that in 1863 the 10 A.M. train reached 123 tons, and in 1872 as much as 232 tons. Similarly the weight of the 5 P.M. train in 1863 was 149 tons, whereas in 1872 it amounted to 257 tons. Although it might be said that the locomotive cost would be the measure of the traffic conveyed for the train mile, yet he thought it must be taken into consideration that the locomotive had been much improved, and probably conveyed a greater load than it did at the time to which Mr. Barlow referred. Perhaps the locomotive engineers were in advance of the permanent-way engineers; but that would not affect the question of what was the proper basis of comparison.

Mr. Francis Fox, of the Bristol and Exeter railway, said one explanation of the increased cost of the permanent way might be that the materials had a certain average life. Fifteen or twenty years ago the mileage of railways was very short; it had increased rapidly up to the year 1869. Probably since that time the growth

had not been so rapid in proportion. If an engineer wanted to bring down the expenses per mile of the permanent way for a time, nothing was better for him than the opening of a long stretch of new line, which would last for a considerable number of years, and the expense of its maintenance would be comparatively small. It was quite possible that at the present time railways were feeling the effects of a greater average age. Up to 1869 the chances were that an average expenditure in renewals of permanent way had not been reached, but by degrees that average was being approached. He could hardly imagine that any engineer in charge of permanent way could feel pleasure in spending money largely. If he had any temptation, it was rather to underspend than to overspend. He did not, therefore, understand why permanent-way engineers should be behind locomotive engineers. He had no doubt that the introduction of steel rails would, after a time, lead to great economy in the maintenance; but as yet, especially on the smaller lines, steel rails had not been used to such an extent as to influence the average expenditure. The question was a deeply interesting one, perhaps more so to small than to large companies, and if any light could be thrown upon it by discussions at this Institution, no one would be more grateful than those who, like himself, were interested in the maintenance of permanent way.

Mr. Ormiston remarked that the calculations before the meeting had been based on the cost per "train" mile, whereas he considered the "carriage" mile to be the correct unit, and he asked if that had increased; he believed not.

Mr. H. S. Ellis considered want of punctuality was the source of a great deal of mischief both to the travelling public and to the railway companies. No doubt high speed was desirable, but if that could only be obtained at the risk of accident, it would be better to modify it in some way. He especially urged the importance of traffic managers altering their respective train-tables whenever daily unpunctuality showed them that it was impossible to perform a journey within the time advertised.

Mr. C. E. Parker-Rhodes said from more than twenty years' experience in France, he hoped that English railways would never be worked in the manner in which French railways were, for it would never suit the commerce and industries of this nation. French railways were all subsidised by the State upon the condition of becoming State property at a fixed period. This arrangement placed them strictly under the supervision of the Public Works Department, and the control was duly exercised

by Government functionaries at each station, both as regarded passengers and goods. The trains in France were timed from one station to another, and the drivers were subject to a penalty for being either before or after time. The system of confining passengers to the waiting-room until just before the train started was also a great inconvenience, and unfair to those who arrived at the station first to secure their seats quietly. Since the discussion on this subject had commenced there had been on an average one accident a day throughout the United Kingdom, proof of which was to be found in the daily papers. Having been allowed, in the course of his travels, to look into the working details of English railways, he was of opinion that their management was entitled to great praise from the public. But there was one thing deficient in the working of every train, namely, the little control which the driver or guard had over the train after it was once in motion. This was the cause of that unpunctuality so continually complained of. Frequently trains were stopped at a distance from a station by a block signal, and the public never knew the reason of the delay. He did not, however, recommend that the speed should be diminished, but rather that it should be increased. He was convinced that it was quite possible to attain a far greater speed with more security than was afforded at present. The great object should be to give the drivers and guards entire control over the trains, and that could only be obtained by having a perfect system of break-power. At present the block system would have to be extended, supplementary lines and sidings provided, necessitating increase of staff and labour and considerable loss of time, without lessening the danger that now existed with every train in the course of its journey. He was glad to have heard from Mr. Allport that greater speed was looked for by railway companies, and by that opinion he was encouraged to bring forward a plan of carriage, self-acting break, and passenger signal, which he was desirous of offering to the companies through the Institution.

Mr. Cudworth said in the arrangement of groups of sidings it was desirable the several sidings should be of about equal length. He had been struck with the want of this in many of the diagrams exhibited. Mr. Footner's was probably the only one which showed equal sidings, but the same result might be arrived at in a different way. Fig. 1 was typical of an objectionable arrangement; Fig. 2 of a suitable one. The modification might easily be made by connecting one end of each lateral siding separately, with the middle line. In this way the siding shortest at one end would be longest at the other, instead of being shortest at both ends, and

equality of length would be more nearly maintained. Mr. Rapier had expressed regret that the Authors of the Papers had not given

FIG. 1.

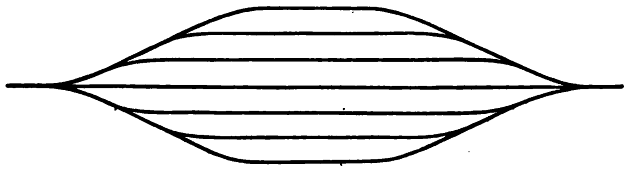
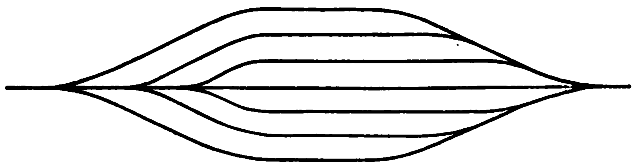


FIG. 2.



particulars of the cost of the sorting sidings, but such particulars would not have been of much good, because the sidings had been a work of time. They were begun many years ago, and had undergone alterations, but he had given the length of sidings and the quantity of land, which was all that seemed needful for the preparation of estimates. At Shildon, with an increasing traffic, and with the trains from the collieries arriving in quick succession at particular hours of the day, the sidings for the reception of traffic before being sorted were insufficient, and it was intended to lay down more. He was glad Mr. Rapier had attempted the problem, and he quite agreed with the result arrived at. But he had put the land much higher than the actual cost, although, on the other hand, he had left out the earthwork, levelling the land, and the cost of a bridge. On the whole, his figures were about what the cost would be at the present time.

Mr. FINDLAY said he had every reason to be satisfied with the manner in which his Paper had been generally discussed; notwithstanding the remark that the Paper was not an exposition of railway management, but merely statistics of the London and North-Western railway, and that railway management was of much vaster dimensions. He freely admitted that there were many things which would justify such a remark, but success must be measured by what was attempted. He had not ventured upon those higher and vaster questions that had been alluded to. As far as he could understand, those subjects were engineering matters,

which he certainly was not competent to deal with—financial matters, parliamentary matters, and questions of general policy. The subject with which he had endeavoured to grapple was, how great railway companies conducted and managed their fast and slow traffic on the same lines of rail, and what arrangement they made for the shunting and working of those trains so as to secure the greatest amount of regularity. That was the proposition he had thought best to explain by the practice of one of the great railway companies. He did not know that the practice of the North-Western was either better or worse than that of its neighbours. The different companies endeavoured, by the experience of each other, to gain an insight into the best mode of working their trains. He offered these remarks in explanation of what Mr. Allport had alluded to as the shortcomings of the Paper. He was not quite certain whether or not that gentleman was in favour of duplicating lines with heavy traffic, such as that between Leeds and Derby; and he wished to know whether it was Mr. Allport's opinion that, although between those two places there were three hundred and twenty-one trains per day, or one hundred and sixty trains passing in each direction, which would give a train every nine minutes during the twenty-four hours—goods trains and passenger trains—he could work twice that amount of traffic on the same line.

Mr. Allport.—No.

Mr. Findlay was glad to receive that modification of what appeared to be a previously expressed opinion to the contrary, because he did not consider it would be possible on the North-Western line between Bletchley and Rugby, with nearly the same number of trains, to accommodate the traffic without duplicating the lines. Sir John Hawkshaw very pertinently asked why the railway companies had committed themselves so readily to the block system. It would be recollected that in the session of 1872, before Lord Buckhurst and the committee on railway accidents, a great deal of evidence was taken upon the subject. Railway companies were then politely told if they did not give an undertaking that, upon their main lines at least, they would adopt the block system, very likely Parliament would make it more stringent, and perhaps compel them to adopt it on branch lines where the companies did not think it necessary. All the great companies gave a pledge that upon their main lines they would adopt the block system and the interlocking of signals. He was bound to say that the system of interlocking, which was very complex and very costly, had, in his opinion, been a bar to trade, for no colliery owner or other

person wishing to connect a branch with a main line of railway could, under the present requirements of the Board of Trade, complete that connection for less than £1,200 or £1,500. Where the companies could do so they made the public pay for it. Where they could not, of course the expense fell upon them. Sir John Hawkshaw also asked what the experience of the managers of railways was in regard to the block telegraph. No doubt it was adopted in too great a hurry, and, so far as the North-Western was concerned, it meant more men, more signals, more sidings, and more interlocking. That very day Mr. Farmer (of Messrs. Saxby and Farmer) had brought to the North-Western office a new instrument, which, no doubt, would be very costly, by which all signals in future were to be worked by a magnetic contrivance, so as to make it impossible for anything to go wrong. He hoped railway companies would, for a time at least, be contented with their present arrangements, which had entailed great expense. The block telegraph did not secure perfect immunity from danger. On the contrary, he believed it had introduced new types of accidents. It was very complicated, the men were liable to make mistakes, and he was afraid railway companies would still continue to have serious mishaps. He had ascertained the cost of signalmen's wages on the 800 miles of block system on the North-Western railway, and he had found that, whereas before they adopted the absolute block the signalmen's wages were £60 a mile per annum, under the absolute block they were £100 a mile per annum, while the number of signalmen had increased from eight hundred and forty to twelve hundred and fifty. With regard to the other point Sir John Hawkshaw alluded to, namely, what he considered the mistake of railway companies in reducing their fares, and throwing away net profits, there could be no doubt that the expenses were constantly increasing against the companies, as had been shown by Mr. Barlow in regard to the permanent way and the locomotives. The companies had passed through a crucial test of high rates for coal, material, and wages, and they had hardly got to the end of it when they found a large proportion of the profits were thrown away by the policy adopted by the Midland Company. It was clear that the dividends of the companies had not been diminished by the expenditure of new capital. What had brought down the dividend of the London and North-Western and of other companies was the increase of expenses, and he would be happy indeed if he could say to his directors that the maximum had been reached; he was afraid they would go on increasing for some time to come. In the face of this

fact it appeared to him to be unwise and impolitic to throw away any source of revenue. Mr. Price Williams' calculations were no doubt clever, but they were intricate, and he was not quite sure that everybody had been able to follow his explanations. If Mr. Price Williams were correct, though he himself did not think so, he had proved that the sooner railway companies arrived at the state in which they would only carry third-class passengers the more profit they would get. Mr. Findlay did not think that this was a proper representation of the case. What had to be considered was the dead weight to be hauled and what was a paying load. If a first-class carriage with its twenty-four passengers at 2*d.* a mile could be filled, which was not always the case, it would be more profitable than the third-class carriage with forty passengers at 1*d.* a mile.

Mr. HARRISON, President, said one advantage to be gained from such a discussion was, that railway managers expressed their opinions one to the other, and he hoped that it would tend to induce them to mutually promote the efficient working of railways. He did not approve the policy of the Midland Railway Company; that policy being to reduce the ordinary classes to which this country since the first introduction of railways had been accustomed, namely, first, second, and third class, to simply first and third class. Society in this country divided itself into three classes; and the mere fact that a slight saving could be effected in the number of carriages and in the fuel was not sufficient to justify the change. Since the Midland introduced their novel idea, he had watched the people who travelled by railway in the north of England, and had come to the conclusion that, at any rate in that district, it would be a great inconvenience if the travelling population were deprived of the opportunity of selecting which of those three classes they thought best. The question of fares was a totally different one from that of reducing the number of classes so far as the public were concerned. He would not offer an opinion as to the advisability of changing the fares from 1*d.*, 1½*d.*, and 2*d.*, to 1*d.*, 1¼*d.*, and 1½*d.*; but as regarded the broad question of public convenience, he had no hesitation in expressing the belief that the policy of the Midland Company was inexpedient. His position upon the Royal Commission on Railway Accidents compelled his silence on all points referring to the question of safety. Many circumstances undoubtedly tended to the increasing cost of permanent way. At the present time he was taking up rails which had been used for thirty-two years; and he did not know where to get others which would last so long. For several years rails had

not been manufactured equal to those of former years. Every time rails were relaid an addition was made to their weight, also to the number of sleepers, chairs, and other things consequent on that increase; and if, as he believed was the case—and it was a perfectly legitimate thing—all the large railway companies were charging that additional cost against their revenue, the extra working expenses would be easily accounted for. Besides, he was not acquainted with any company that did not at the present time charge the whole of the difference between the cost of steel and iron to the ordinary revenue of the year. These items, no doubt, added considerably to the cost of maintenance. The diagrams (Plate 7) represented some sidings which had lately been placed in the neighbourhood of Newcastle, and would, he thought, be sufficiently explanatory in themselves, without any descriptive remarks.

March 2, 9, and 16, 1875.

THOS. E. HARRISON, President,
in the Chair.

THE discussion upon the Papers, Nos. 1,419, 1,406, and 1,421, by Messrs. FINDLAY, CUDWORTH, and J. T. HARRISON respectively, occupied the whole of these evenings.

At the Meeting of March 2nd the following Candidates were balloted for and duly elected:—General ARTHUR MORIN, and Sir CHARLES WHEATSTONE, F.R.S., as Honorary Members; ROBERT CARR, JEREMIAH HEAD, WILLIAM KIRTLEY, JOHN HAWTHORN KITSON, and JOHN WRIGHT, as Members; and CHARLES JOHN ALBRECHT, WILLIAM WORBY BEAUMONT, Captain ARCHIBALD CUTHBERT BIGG-WITHER, WILLIAM BOOTH BRYAN, WILLIAM DARNBROUGH CAMERON, ALFRED CHAPMAN, JAMES GREGSON CHAPMAN, DONALD MACDONALD FORD GASKIN, MATTHEW GRAY, HERBERT GROVES, WALTER JOHN HAMMOND, JAMES ALEXANDER CAMERON HAY, JESSE HILDRED, HERBERT EDGELL HUNT, JOHN JOICEY, JOSEPH PARRY, JOHN ROGERSON, JOSÉ GIBERGA TINTORER, Stud. Inst. C.E., WILLIAM TWEEDIE, Stud. Inst. C.E., and FRANCIS WILTON, Stud. Inst. C.E., as Associates.

It was announced that the Council, acting under the provisions of Sect. III., Cl. VIII., of the Bye-Laws, had transferred HENRY CHRISTOPHER DIGGES LA TOUCHE from the class of Associate to that of Member.

Also that the following Candidates, having been duly recommended, had been admitted, under the provisions of Sect. IV. of the Bye-Laws, as Students of the Institution:—MAURICE FREDERICK FITZGERALD, ARTHUR FRANKLIN GUILLEMARD, SAMUEL COLLETT HOMERSHAM, Jun., DONALD MACFARLANE, HENRY SIDNEY WHITE, LAWRENCE HERSEE WHITMORE, and EDWARD WALTER NEALOR WOOD.

March 23, 1875.

THOS. E. HARRISON, President,
in the Chair.

No. 1,416.—"The Hull Docks."[1] By Sir William Wright, Assoc. Inst. C.E.

In the beginning of the reign of Queen Elizabeth an Act of Parliament was passed providing for the establishment of legal quays and wharves in all the ports in this country, Hull only excepted. It is hard to explain why this exception was made, unless there were difficulties in the way of forming a quay at Hull, as would appear to have been the case from the oldest maps to which reference can now be made.

Owing to the situation of the Old Harbour, with the citadel on the east and with houses extending to the very brink of the river on the other side, no room was really left for the construction of a legal quay, or for the thoroughfare in connection with it. However, the result was that the Revenue suffered greatly in consequence of extensive smuggling transactions. It is recorded that, in the year 1746 especially, many illegal practices were discovered; and surveyors and other officers sent down there reported that, in the interests of the public revenue, it was absolutely necessary legal quays should be established. They drew attention to the fact that, there being no public thoroughfare along the side of the harbour, the officers had great difficulty in collecting the customs, and the goods had to be watched both on board ship and also on board the lighters or craft which took them to shore, in case of discharge in the Humber, whilst the position of the houses and other property along the Old Harbour gave peculiar facilities for smuggling. Many deserving officers were found to have been dismissed from the service of the customs because they had been supposed to connive at evasions which the state of the harbour had rendered it impossible for them to

[1] The discussion on this Paper was taken in conjunction with the succeeding one, and occupied portions of two evenings, but an abstract of the whole is given consecutively.

control or prevent. This determined the Government to take direct action with a view to obtain legal quays at Hull as at other ports. But the owners of private property abutting on the Old Harbour at the west side of the river Hull, including the Municipal Corporation of the town, who were interested in that property, were opposed to the scheme, and the movement of the Commissioners of Customs to obtain the establishment of legal quays met with decided and almost general local opposition and resistance. So matters drifted on until about the year 1764, when a specific suggestion was made that legal quays should be formed upon the east side of the harbour, along what was called the "Garrison Ground"; and in the year 1767 the Corporation introduced a bill into Parliament for the construction of a dock on the east side, though still unwilling to promote the formation of a legal quay, and the consequence of this was that the customs authorities resisted the bill, and it failed. It was then suggested that legal quays should be established on the west side of the harbour, but to this the customs authorities objected.

Further reports ended in the Customs Commissioners insisting upon the dock and the legal quay being placed together; and the Corporation, still adhering to the plan of an east dock, but resisting the connexion of the legal quay with it, again attempted to obtain parliamentary sanction to their scheme, and failed. Thereupon, the customs authorities having proposed that they themselves should buy or rent land in Hull for a legal quay and custom-house, the Corporation again began negotiations, and as their local interests were determined that the quay should be in front of the existing property on the Old Harbour, the Customs Commissioners appear to have at last consented to the quay being so established. Whilst, however, these negotiations were going on, some parties who were interested in the port of Gainsborough invited the commissioners to go to Gainsborough and there form a legal quay. This proposal aroused the Hull merchants, and ultimately a suggestion was entertained for making a custom-house and legal quay on the Old Harbour. But this scheme would have necessitated the banking-in of the Old Harbour, which was opposed by land-owners having property higher up the river, and in consequence of the opposition this scheme also failed.

Mr. Grundy was now appointed to consider the matter, and he suggested three modes of proceeding, one of which was the conversion of the old ditches on the west side of the town into docks, a plan which was eventually adopted. Thus the older portion

of the present system of docks was early shadowed forth. This scheme was brought before the Corporation of Hull, they having certain claims on the Old Harbour in the shape of Water Bailiffs' Dues; while another body collected what were called "Primage Dues." The result being of importance to both bodies, a great deal of discussion took place on the subject between the Corporation and the Trinity House. Thus in the Treasury Book of 1773 it is found that, at a meeting at which Lord North and other members were present, Sir William Musgrave said that "the commissioners did not wish to diminish the trade of the town of Hull, but that they had determined that they would be trifled with no longer, and that, although they wished to proceed in the most friendly manner with the town, yet should they find great local unwillingness to co-operate with the Board for the general good, they should then certainly revert to what was before the Lords of the Treasury the previous year, viz., the making of a port at Gainsborough, and do such other things in the neighbourhood of Hull as for the trade of the country it appeared to them they ought to do." In fact, it was now made clear to the Corporation of Hull, and to the representatives of the mercantile interests there, that the system of smuggling must be put an end to, that such steps must be accompanied by the construction of proper dock accommodation and legal quays, and that the utmost that parties could expect was fair compensation for the loss of any exclusive advantages. The result, as appears by a Treasury Minute of the 11th of March, 1773, was a distinct proposition to the Corporation to undertake the formation of a dock, which they, however, declined to make. Overtures were then made that the Trinity House, who had the chief interest because of their revenues from shipping, should do so. However, neither corporation would undertake the new works, but they both became subscribers in the Company which it was now determined to form, and to whom it was left to raise the necessary funds to carry out what was at the time considered a hazardous speculation.

In the year 1774 the first Act was obtained. This, after reciting the Acts of Elizabeth and Charles containing the exemption in favour of Hull before referred to, went on to recite that "after the passing of this Act his Majesty might assign and appoint such open places, quays, or wharves at Hull on the west side of the harbour and on the walls adjoining the town's ditches to be level open places, quays, and wharves," and so on. Here, then, is the first enactment establishing the

principle of there being new docks with legal quays in the position represented formerly by the "town's ditches." And further, that there should be also the power of setting out legal quays upon the west side of the harbour along the frontage of the Old Harbour proprietors.

The Act goes on to recite that it is necessary that a basin or dock with sluices, roads, &c., shall be provided, and it enables the Company to make them. It was also arranged that the Corporation, the Trinity House, and the Charter House of Hull were to be permitted to take shares in the capital of the Company. The Crown granted land, and £15,000 in money, to aid in the construction of the works. Borrowing powers were conferred upon the Company in addition to their share capital, and commissioners were appointed to control the undertaking generally. The Company was incorporated by the style and title of "The Dock Company at Kingston-upon-Hull," which name it has ever since retained. Tonnage and other rates were granted to the Company upon shipping and goods in consideration of their undertaking the work. One of their first acts was to seek an interview with Mr. Berry, the Engineer of the Liverpool Docks, and in the month of August it was decided that his plans for the intended new dock and quay should be carried into execution. The work was prosecuted with vigour, and the dock, now known as the "Queen's" Dock (but first called the "Old" Dock), was completed in 1778. The result of the formation of this dock was the speedy and large increase of the trade of the port, so that the question of further dock accommodation was started before the end of the eighteenth century.

The whole of the land granted by the Crown had not been exhausted in the formation of the "Old" Dock; still it remained for some time a vexed question as to whether the Company should make another dock so early as twenty years after the commencement of the first. Again negotiations took place between the Dock Company, the Municipal Corporation, and the Trinity House. The dues received by these two last-mentioned bodies had largely increased since the opening of the dock. Indeed, in twenty years the dues payable to the Corporation had increased sevenfold, and in the case of the Trinity House rates it is believed that the increase was proportionately large. These bodies, therefore, were now not unwilling to assist in the formation of another dock. The Crown also agreed again to give assistance, and did so by the sale of further land at a low price. In 1802 an Act was obtained under which the "Humber" Dock was made, the second constructed

at Hull, and opened in the year 1809. In 1825 the "Prince's" Dock was made. This was constructed at the sole cost of the Company. The trade of the port now increased immensely. The population of Hull had trebled within a short time; and, accordingly, in the year 1840, the Company went to Parliament with a bill to authorise the formation of another dock east of the Old Harbour. To the west of the Old Harbour the whole of the then town had been inclosed by the three docks already described. It was originally intended to construct this dock (since called the "Victoria" Dock) with an entrance from the Humber only, but it was subsequently determined to add the entrance into the Old Harbour. This bill, on account of local opposition, had to be withdrawn; but in 1844 application was again made to Parliament for power to construct in addition, a basin to the "Victoria" Dock, also the "Railway" Dock, to open out of the Humber Dock, and close to the terminus of the North-Eastern (then the Hull and Selby) railway. The power to make these docks was not obtained without severe struggles with many local bodies and interests, but the Company was successful.

Power was now obtained to lay rails along the quays of the docks for facilitating the conveyance of goods to and from the railway terminus. The Company were also at this time authorised to erect warehouses in the immediate vicinity of the docks. Of these the "Railway" Dock was finished in 1846, and the "Victoria" Dock in 1849; and the trade of the port by this time ranked next to London and Liverpool.

Subsequently the "Victoria" Dock was considerably enlarged; and in 1861 an Act was obtained authorising the Company to construct another dock on the west foreshore of the river Humber. This was finished in 1869, having been extended, in the course of its construction, considerably beyond what was originally contemplated. It was opened by H.R.H. the Prince of Wales on the 29th of July, 1869, when it received its present name, the "Albert" Dock.

The Queen's Dock comprises a water area of about 10 acres. Its length is 1,703 feet, and breadth 254 feet. The depth of water on the sill at average spring tides is 20 feet 6 inches. The first stone was laid on the 19th of October, 1775, by Mr. Joseph Outran, then mayor of Hull, one of the commissioners under the first dock Act. The Engineer was Mr. John Grundy, although the first designs were prepared by Mr. Berry, of Liverpool. Mr. Luke Holt was the Resident Engineer. In 1814

the lock and basin of this dock were rebuilt by Mr. Rennie. The first ship entered the dock on the 22nd of September, 1778, and the legal quay was opened for business at Michaelmas 1779. The northern quay is devoted chiefly to the discharge of deals and timber, and almost the whole length of the dock along its north side is flanked by extensive timber-yards, the property of the Company, and occupied by merchants as their tenants. On the south side vessels engaged in various trades are accommodated. The quay is covered to a depth of about 30 feet by sheds almost along its whole length, whilst to the southward of this, on the other side of a wide road for cartage and railway lines, are several of the warehouses of the Company, in which are stored large quantities of goods, including hemp, flax, grain, &c. Here there are extensive cellars for the storage of oil. On the quays of this dock are seven cranes for discharging and loading vessels At the south-east corner of the dock is the principal yard of the Company, where a great part of the work carried on by the Engineer's staff is performed.

The Humber Dock contains upwards of 7 acres of water space. The first stone was laid on the 13th of April, 1807, by Mr. Henry Maister, the then Chairman of the Company. Its length is 904 feet, and breadth 342 feet; the width, of the entrance into the Humber is 41½ feet, and into the "Princes" Dock 35½ feet. The depth of water on the sill at neap tides is 21 feet, and at ordinary spring tides 26½ feet. The Engineers were Mr. John Rennie and Mr. William Chapman, and the Resident Engineer was Mr. John Harrop. Sheds are erected on the quays almost entirely round this dock. It is occupied principally by steamers engaged in the Hamburg, Rotterdam, Antwerp, and French trades. The quays are laid with rails, and there are four cranes of large size, besides smaller ones attached to the sheds.

The Prince's Dock occupies upwards of 6 acres of water area. The first stone was laid on the 10th of December, 1827, by Mr. J. C. Parker, the Chairman of the Company, and it was finished and opened in 1829. Mr. James Walker, Past-President Inst. C.E., was the Engineer of the works, and Mr. John Timperby the Resident Engineer. Its length is 604 feet, and breadth 407 feet. The entrance lock between it and the Humber Dock is 120 feet long, and 36 feet 6 inches wide. The depth of water at neap tides is 15 feet, and at spring tides 20 feet 6 inches. Sheds extend along the east and west sides, and the greater part of the south side of the dock, and there are five cranes on the quays, besides smaller ones attached to the sheds.

THE RAILWAY DOCK is 2 acres 3 roods 2 poles in extent. Its length is 700 feet, breadth 180 feet; the depth of water on the sill at neap tides is 21 feet, and at spring tides 26 feet 6 inches. The foundation stone was laid by Mr. Huffam, then Secretary of the Company, on the 28th of May, 1845. The late Mr. J. B. Hartley, M. Inst. C.E., was the Engineer, and Mr. Lane the Resident Engineer. The Contractors were Messrs. Bowers and Murray, and the dock was finished and opened in 1846. The north, west, and south quays are covered by sheds, and on the north and south quays there are cranes capable of lifting 20 tons. Along the south side, beyond the sheds, is a block of some of the finest warehouses belonging to the Company. In this dock steamers of the largest class, trading with Russia, Norway, Sweden, &c., discharge and load, and there is probably no dock in the kingdom where the same amount of work is done in an equal space.

THE VICTORIA DOCK covers upwards of 20 acres of water space; there are besides three basins which comprise upwards of 6 acres more. The foundation stone was laid on the 1st of November, 1846, by Mr. Beadle, the Chairman of the Company. The Engineer was the late Mr. J. B. Hartley, and the Resident Engineer Mr. Edward Welsh, M. Inst. C.E. Its length is 2,000 feet, and breadth 378 feet. The depth of water on the sills at neap tides is 22 feet, and at spring tides 27 feet 6 inches. It has two entrances—one into the Humber and one into the Old Harbour. The width of the former is 60 feet, and of the latter 45 feet. The quays of this dock are also provided with lines of railway, behind which are extensive yards, the property of the Company, let to various firms engaged in the timber trade, to which trade this dock is chiefly devoted. At its east end, and also to the south, are two extensive timber-ponds, the former upwards of 11 acres, and the latter 14 acres in extent; both of which are almost always fully occupied. In the immediate vicinity of this dock are two patent slips, the property of the Company, for hauling up and repairing vessels. They are capable of accommodating ships of 2,000 tons burden and upwards. On the quays are several cranes, capable of lifting from 10 tons to 60 tons each.

THE ALBERT DOCK contains upwards of 24 acres of water space. It is 3,400 feet long, with an average width of 300 feet. The depth of water on the sill at neap tides is 23 feet, and at spring tides 28 feet 6 inches. The length of the entrance lock is 300 feet, and its width 80 feet. The first stone was laid by the Author, the Chairman of the Company, on the 21st of May, 1864. It was

opened in July 1869, by H.R.H. the Prince of Wales. Sir John Hawkshaw, Past-President Inst. C.E., was the Engineer, and Mr. J. Clarke Hawkshaw, M.A., M. Inst. C.E., the Resident Engineer. This dock is surrounded by lines of railway, and has warehouses along its northern quay. The ground-floor of the warehouses is left open, with doors that can be closed if required, so that it can be used either for the storage of goods or as sheds. On the north quay there are several ordinary cranes, capable of lifting from 15 tons to 30 tons each, besides hydraulic cranes attached to the warehouses, both in front and behind the buildings. At the east end, on the quays of a creek specially constructed for the purpose, the North-Eastern and the Manchester, Sheffield, and Lincolnshire Railway Companies have shipping places, with cranes and other conveniences. Between this and the Humber Dock is an extensive basin, of nearly 7 acres area, a portion of the centre of which is, however, now being filled in, whereon to erect station accommodation for the Manchester, Sheffield, and Lincolnshire Railway Company. From the depth of water and the width of the entrance, the largest vessels, with the solitary exception of the "Great Eastern," can enter this dock.

Two additional docks are now being made, immediately beyond and to the westward of the Albert Dock, upon foreshore land, the property of the Company, which was purchased from the Crown at the time the Albert Dock was being constructed. The one to the east will be 8½ acres in area, 1,390 feet long and 220 feet wide, with an entrance from the Albert Dock, 50 feet in width. It will be especially adapted for the accommodation of steamers, although available for sailing-vessels. Extensive sheds and powerful cranes will be erected on the quays, and all recent improvements in the way of appliances, &c. The second dock, to the west of this, with an independent entrance from the river Humber, and a lock 250 feet long and 50 feet wide, will be 1,802 feet long, and 250 feet wide, and comprise an area of water of 10 acres. This dock is intended for general trade, and will be furnished with sheds and cranes of the most approved character. The dock is being so constructed as to be capable at any time of large increase, even to as much as 30 acres. These new works are in course of construction from plans by the Engineer of the Company, Mr. R. A. Marillier, M. Inst. C.E., Sir John Hawkshaw being the Consulting Engineer. The whole of the masonry will be executed under the superintendence of the Engineer, by men in the employment of the Company; the only contract, that for the excavations, has been let to Messrs. John Bayliss and Son. When these

additional works are completed, the water area of the docks and basins will amount to about 103 acres, exclusive of the two timber-ponds, which comprise 25 acres.

The warehouses of the Dock Company are twenty-four in number, five being situated on the quays of the Queen's Dock, two to the south of the Prince's Dock, two at the Humber Dock, four at the Railway Dock, three at the Victoria Dock, and eight at the Albert Dock. They are capable of storing about 500,000 quarters of grain and seed, or a proportionate quantity of other articles. The goods in these warehouses consist for the most part of grain, seed, hemp, wool, guano, and oil, with smaller quantities of other articles.

The following table of the tonnage of vessels frequenting the port, and paying dues to the Company, will show the increase since the first dock was constructed:—

In 1775	109,491 tons.	In 1835	413,135 tons.
1785	117,743 "	1845	710,038 "
1795	150,536 "	1855	782,411 "
1805	174,875 "	1865	1,262,763 "
1815	265,232 "	1874	over 2,000,000 "
1825	448,911 "		

In the year 1775 the gross receipts of the Company were £4,663; in 1873 they amounted to £176,716; and for 1874 they will be considerably in excess of this sum.

The navigation of the river Humber is easy to vessels of the largest draught. Other railway companies besides the North-Eastern have lately had their attention turned to the increasing trade of the port; and there can be little doubt that if the present enlightened management of the affairs of the Dock Company continues, Hull has before her an increase of trade and prosperity greater even than that which has already taken place.

No. 1,417.—"The Construction of the Albert Dock at Kingston-upon-Hull."[1] By JOHN CLARKE HAWKSHAW, M.A., M. Inst. C.E.

IN the year 1839 there were only three docks at Hull, viz., the Old Dock, now known as the Queen's Dock, opened on September 22, 1778, Mr. Grundy, Engineer; the Humber Dock, opened June 30, 1809, Messrs. Rennie and Chapman, Engineers; and the Junction Dock, now known as Prince's Dock, opened June 1, 1829, Mr. J. Walker, Past-President Inst. C.E., Engineer.[2] The water area of these docks was 23 acres 18 poles.

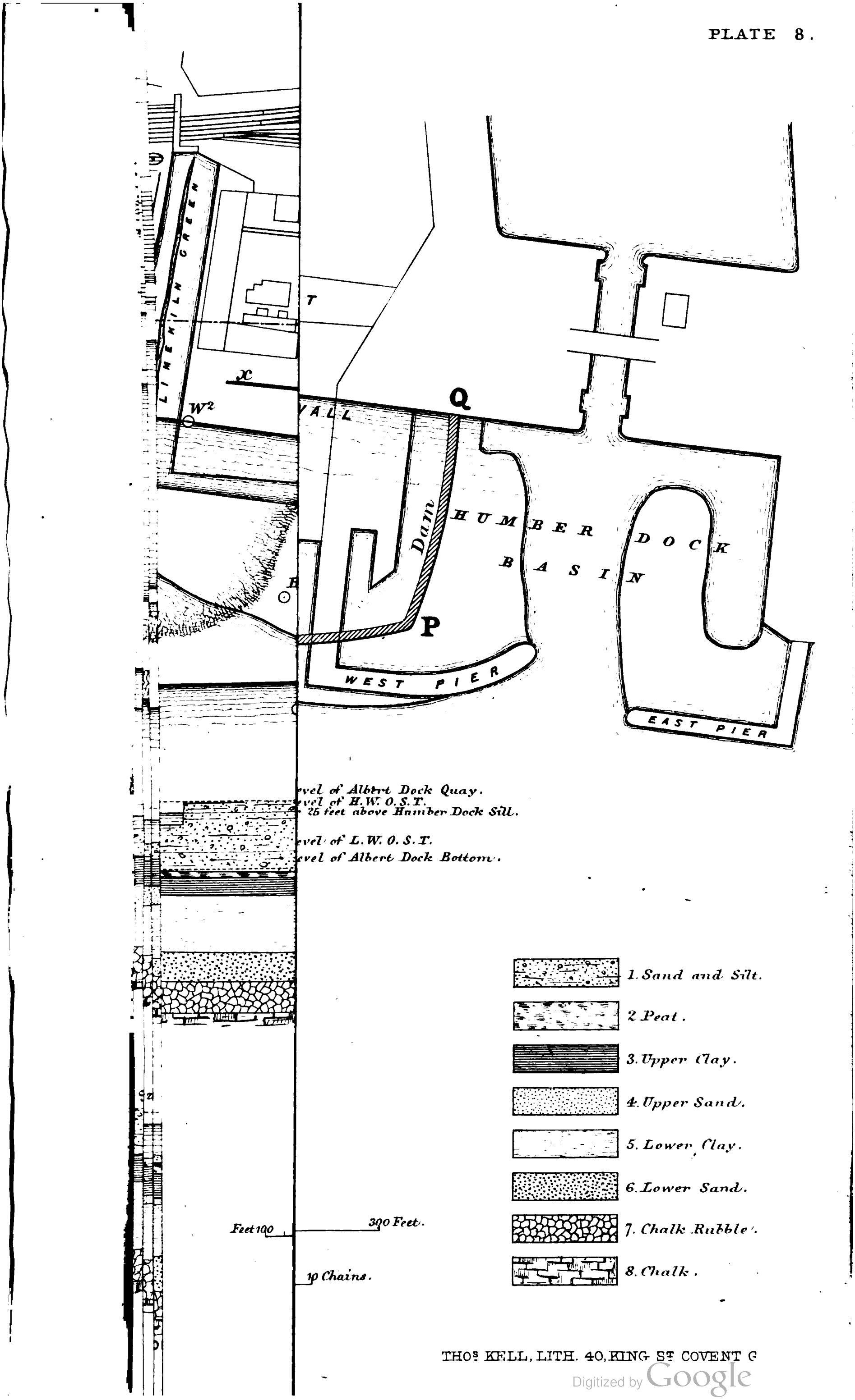
Since then three additional docks have been constructed; the Railway Dock (2 acres 3 roods 9 poles), opened in the year 1846, and the Victoria Dock (12 acres 2 roods 13 poles), opened in the year 1850, both constructed under the superintendence of Mr. John Hartley, M. Inst. C.E.,; and lastly, the Albert Dock (24 acres 23 poles), Sir John Hawkshaw, Past-President Inst. C.E., Engineer, opened by H.R.H. the Prince of Wales, July 22, 1869. The area of the Victoria Dock is now 20 acres 4 poles. It was enlarged before the Albert Dock was begun, and two timber-ponds were constructed at the same time, having an area of 25 acres. For these works Sir John Hawkshaw was also the Engineer.

In the year 1861 the Hull Dock Company obtained an Act to construct a dock, to be called the Western Dock, since named the Albert Dock, on the foreshore and lands adjoining to the westward of the Humber Dock basin, to enlarge the Humber Dock basin, and to divert a part of the Hull and Selby railway, and to make a junction with it near the borough boundary.

In the year 1866, after the commencement of the works for the new dock, a further Act was obtained for its extension to the westward. And in the year 1867 a third Act to alter the line of the embankment as then authorised, by diverting it to the southward, and for the prolongation of the first embankment for a distance of 3,000 feet to the westward. Powers were given by this Act to reclaim the 60 acres of land inclosed by these embankments, and

[1] The discussion on this Paper was taken in conjunction with the preceding one, and occupied portions of two evenings, but an abstract of the whole is given consecutively.

[2] *Vide* Transactions Inst. C.E., vol. i., p. 1, "An Account of the Harbour and Docks at Kingston-upon-Hull." By Mr. Timperley.



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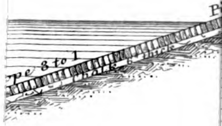
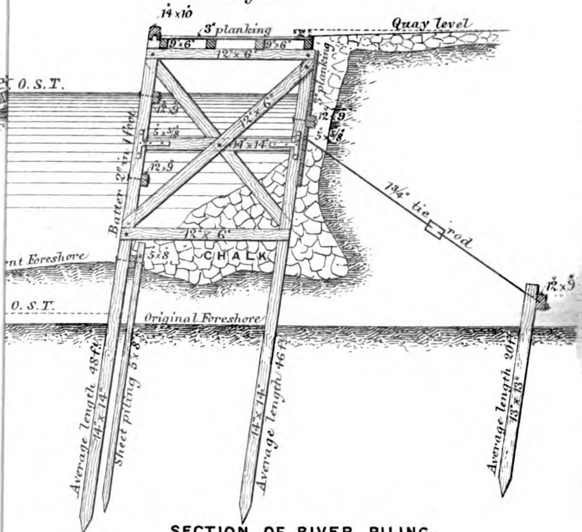
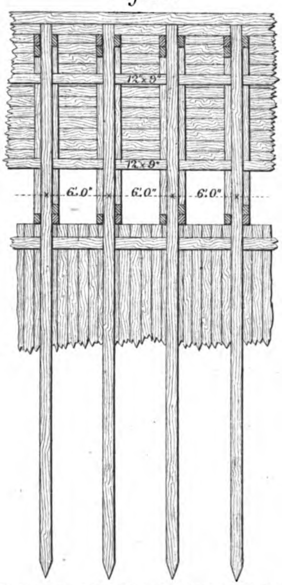


Fig: 15.



SECTION OF RIVER PILING.

Fig: 16.



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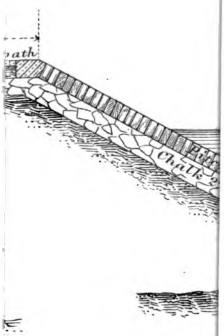

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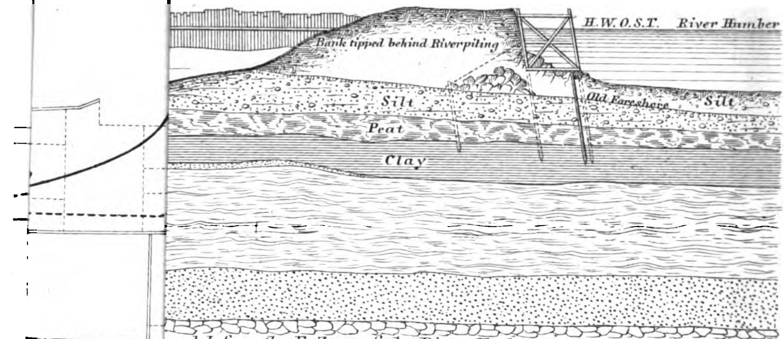

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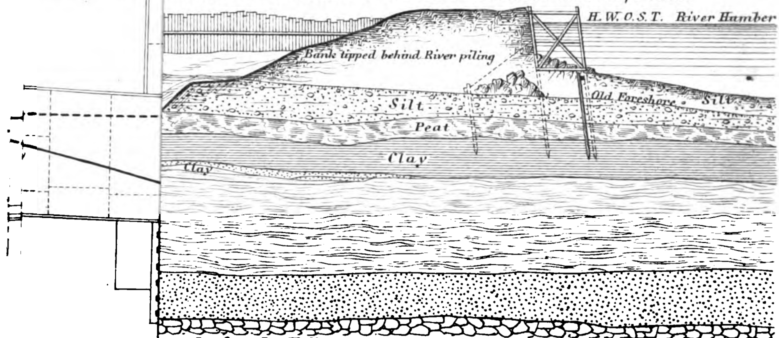

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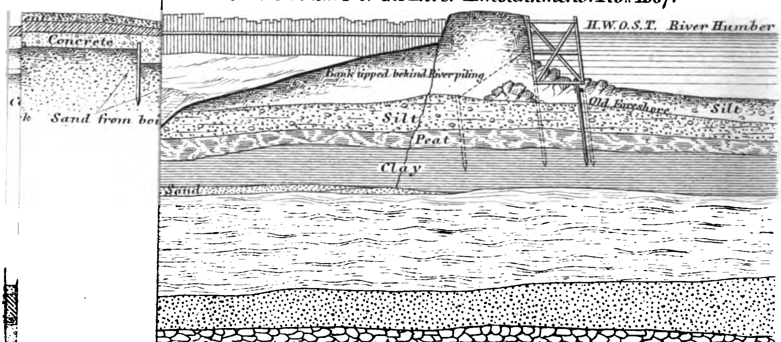

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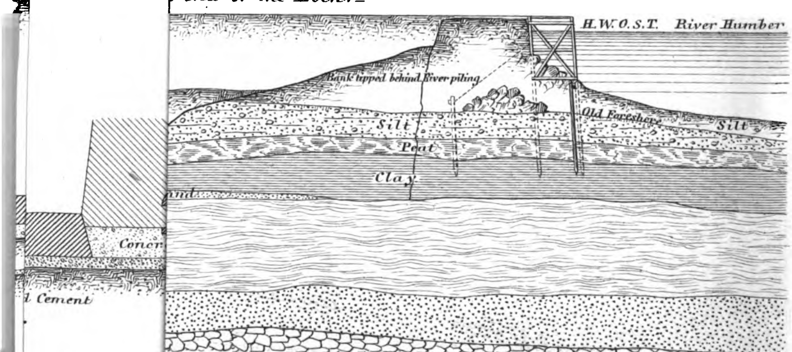

ock as completed.

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to purchase it for the purposes of the Dock Company; also to purchase about 75 acres of foreshore extending 4,500 feet to the westward of the land to be reclaimed.

Before proceeding to describe the progress of the works, and the difficulties which necessitated alterations in Sir John Hawkshaw's original designs, it will be advisable to describe the site selected for the dock, and the nature of the strata available for the formation of the embankments, for the foundations of the walls, and for other purposes connected with the works.

Site of the Albert Dock. (Plate 8.)

By far the larger part of the area consisted of muddy foreshore with a few private wharves and three slips for small vessels adjoining. The main goods line of the North-Eastern Railway Company, and numerous sidings, extended along the existing river margin and over the site of the proposed North Quay; these were moved, in 1864, on to land purchased by the Dock Company. At the east end of the dock there was a small tidal basin called the Limekiln Creek. Its quays were occupied by the North-Eastern and Manchester, Sheffield, and Lincolnshire Railway Companies. Until adequate accommodation could be provided for these railway companies elsewhere, it was necessary to leave the entrance to this basin open, and this materially affected the arrangement of the embankments and the progress of the works.

Nature of the Strata. (Plate 8.)

The foreshore near the quays was covered with a deposit of Humber silt, or, as it is locally called, warp, in some places 30 feet thick. This deposit thinned out towards low-water line; it was succeeded by a bed of peat, varying in thickness from 2 feet to 8 feet, and ranging from low-water level at the west end of the dock to 12 feet below that level at the east end, where it attained its maximum thickness of 8 feet. Beneath the peat were three beds belonging to the upper part of the glacial drift, consisting of two beds of boulder clay separated by a bed of sand. In the middle of the dock the top of this sand-bed was at or near the dock bottom, below which it extended to a maximum depth of 19 feet. From the centre it dipped gradually towards the ends of the dock, diminishing in thickness, and finally thinning out. The sand was fine grained mixed with some chalk. It was not used for mortar, and only to a small extent for concrete. The clay composing the upper and lower beds was compact, and generally

without potholes of sand and gravel; the upper bed was full of rounded and angular fragments of various rocks of small size; the lower bed was free from stones. The clay was separated from the chalk by a bed of sand 16 feet thick. Considering the great depth of this bed of sand, 80 feet below quay-level, it did not appear likely to affect the foundations; nevertheless this sand was the cause of much delay in carrying out the works.

Owing to the marked contrast presented by these beds, their nature was accurately ascertained by numerous borings before the work was begun. In one case only, at the lock entrance, a boring proved a source of error. This boring passed through a local thickening of the bed of sand between the two clays, and gave rise to exaggerated notions of its importance at the lock entrance.

General Description of the Dock. (Plate 8.)

The dock, as designed for the Act of 1861, was 2,500 feet in length. After the Act of 1866 had been obtained the length was increased by nearly 1,000 feet. The dimensions are, length 3,350 feet, width at west end 200 feet, maximum width 430 feet. Its area is 22·8 acres, not including the area of the lock entrance. The depth of water at high water of ordinary spring tides is 29 feet, of neap tides 24½ feet, and the height of the quay above the dock bottom is 35 feet 3 inches. The total length of the quays is 7,200 feet; of this a length of 5,580 feet is formed by a wall, and the remaining 1,620 feet by a pitched slope, having an inclination of 1¼ to 1 along the south side of the dock, and of 3 to 1 at the west end. There are three stone jetties on the pitched slope, which constitutes part of the south side of the dock. Two of these jetties are occupied by coal drops. The lock is 320 feet in length between the sills, and its width is 80 feet. The total length of the entrance is 656 feet. There is a depth of 27 feet 3 inches of water on the sills at high water of ordinary spring tides, and of 22 feet 9 inches at low water. The area of the Humber basin has been increased by 3¾ acres, and the Railway Creek, 335 feet in length and 60 feet in breadth, with a depth of water of 19 feet at high water of ordinary spring tides, has been made adjoining it. A semicircular structure of timber connects the wall on the south side of the lock with the timber wharfing of the river frontage. The wharfing extends for a distance of 2,420 feet to a point opposite the end of the dock. From thence there is a pitched slope having an inclination of 2 to 1, and a length of 3,200 feet. This slope abuts

against the piling, forming the extension of the sewer outlet at the borough boundary. The total area occupied by the dock, lock, basin, quays, and land already reclaimed at the west end of the dock is 76 acres. There remain 120 acres of foreshore, the property of the Dock Company, which can be used for the extension of the works as the trade of the port increases.

Rails are laid all round the dock, crossing the lock by a swing bridge worked by hydraulic power. There is a junction with the North-Eastern Railway Company's goods line at the west end of the dock near the borough boundary, and the lines from the North Quay are continued along the basin wall, and extend from thence to join the lines round the other docks.

Method of carrying out the Works. (Plate 8.)

The cofferdam M N O was commenced in October 1862, and was finished from the point M as far as the old quay forming the river frontage by March 1863. From the point N a second dam, N P Q, was driven parallel to the existing quay, for a distance of 420 feet to the east, and from thence, in a direction at right angles to the former, to join the old Humber Basin wall. In March 1863 the excavation for the Railway Creek was begun. The material excavated was tipped to form the bank R S M, and to back up the river wharfing, which was driven only as far as the west side of the Limekiln Creek, so as not to obstruct the entrance to that creek until accommodation had been provided in the New Railway Creek for the Manchester, Sheffield and Lincolnshire and the North-Eastern Railway Companies. The foundations for the North Basin wall were completed in October 1864, and the foundation stone was laid by Sir William Wright, Deputy Chairman (now Chairman) of the Dock Company. This wall was finished in March 1865; and the part of the West Basin wall against which the cofferdam M N O abuts was completed soon afterwards. The dam N P Q was removed before the end of 1865, the part of the basin included within it having been previously excavated to the required depth. In order that the excavation for the lock might be more conveniently carried on, an opening was left in the dam M N O between the points N O. This opening was necessarily closed before the removal of the dam N P Q. The material from this end of the dock was taken to form the two cross-banks T U, T′ U′, and to make an embankment between their extremities, behind the river piling. An area of about 10 acres was thus inclosed, including all the west end of the dock, as designed for

the Act of 1861. When the water was excluded from this area, in March 1865, the excavation for the dock walls was begun and the embankment was made from the extremity of the cross-bank T U eastward behind the river piling, which had been finished with the exception of a small portion left open to give access to the Limekiln Creek. This gap was not closed until February 1866.

The first stone of the dock wall was laid on the 13th of November, 1865, at the point V. Throughout the latter part of the year 1865 the excavation proceeded with great rapidity. An embankment was made along the line U′ W, the foot being protected by a mound of chalk, deposited in advance. The river slope was also protected against the wash of the tide by a covering of chalk. By February 1866 the water was excluded from all the area to the west of the bank T′ U′ required for the dock. For this extension the necessary powers were obtained by the Act of 1866.

Thus the area to be occupied by the dock was divided into three sections. Whilst the banks were in progress a large amount of silt was deposited over the areas inclosed by them. The waters of the Humber estuary contain much solid matter in suspension, which was deposited when the flow of the current was checked. In addition to this, material was washed from the ends of the tips and sides of the embankments, this latter quantity increasing as the banks were completed, and as the width of the opening which gave access to the tidal waters was diminished. Owing to these causes the level of the foreshore inclosed by the banks was raised 12 feet, necessitating the removal of much more than the estimated quantity of material.

Dock Wall. (Plate 9.)

The design adopted for the dock wall is shown in Figs. 1, 2, and 3; but only part of the wall was built in that way. The delay caused by a failure of the river bank determined the alteration in the design. The substitution of a solid for the arched wall, though most advisable when the circumstances of the case are considered, is to be regretted, as the arched wall (Figs. 1, 2, 3), though more costly than the designs afterwards adopted, has the advantage of a much broader base with about the same quantity of masonry, and affords good foundations for such cranes as may be subsequently required on the quay. The foundation of the arched wall consisted of a layer of concrete placed on the second bed of clay at a depth, in some cases, of 19 feet below the dock bottom. A length of 972 feet of arched wall was constructed on

each side of the dock. The masonry extended to a depth of 4 feet below the dock bottom, and the thickness of the concrete was, on an average, 10 feet. The greater part of the excavation for these foundations was in sand containing much water. Two rows of 12-inch sheet piling were driven 30 feet apart, and the space between them, after the sand had been removed, was filled with concrete to the required level. Probably the sand-bed extended beneath the river bank into the bed of the Humber, as great difficulty was experienced in preventing the sand from flowing through the interstices between the piles and leaving a cavity below the clay. The compact nature of the upper bed of clay prevented its settling down, even when a cavity of considerable size had been formed by the removal of the sand beneath, and was mainly the cause of the failure in the river bank.

On the 17th of September, 1866, the water from the Humber burst into the foundation at the east end of the arched wall on the south side of the dock, carrying with it a large part of the sand-bed. The bank gradually settled down, and two rents were formed about 150 feet on each side of the point of maximum settlement, through which the water poured into the dock. Two breaches were thus made in the river bank. By working night and day these were made good on October the 13th, and the pumps were at once started to remove the water from the inundated portion of the works. A 12-inch syphon was also placed over the bank, and for a time the water was lowered at the rate of 12 inches a day.

As the western cross-bank had not been cut through when this accident happened, the works were not stopped in the western part of the dock. In this section the first foundation was ready for the masonry at the end of June 1867. The wall, which was of the section shown in Fig. 4, could be built more rapidly than the arched wall; it also required less extensive foundations. On the north side of the dock, where the sand-bed thinned out at the east and west ends, the masonry was placed on the clay at a depth of 3 feet below the dock bottom, without sheet-piling (Fig. 8).

The sections adopted for the south wall, after the failure of the bank, are shown in Figs. 5 and 6. At the west end, where the sand extended to 19 feet below the bottom of the dock, two rows of close sheet piles were driven 20 feet 9 inches apart, the back row 25 feet long and the front row 15 feet long. The sand was excavated to a depth of 8 feet below the dock bottom, and was replaced by concrete up to 4 feet below the same level. East of the arched wall, on the south side of the dock, the back piles were 33 feet long, this being the narrowest part of the bank.

The walls were of stone similar to Bramley Fall, principally from Horsforth near Leeds. The material used in the backing was from Spofforth and also from Mexborough. The mortar was made of blue lias limestone from Lyme Regis, burnt in kilns or clamps on the works. The lime, after being slaked, was ground for twenty minutes with sand and water, the proportions of sand to lime being 2 to 1.

Lock Foundations. (Plate 10.)

Judging from the strata excavated for the foundations for the return wall near the Railway Creek, and from borings, it seemed probable that a bed of sand about 8 feet thick would be found between the upper and lower beds of clay, at a depth varying from 50 feet to 54 feet below the coping. It was therefore decided that the same plan should be adopted for the foundations of the lock as had hitherto been successfully carried out for the dock walls, *i.e.* to remove the upper bed of clay and sand below it, and to place the masonry on concrete resting on the bottom clay. This would have given an average thickness of 14 feet of concrete below the masonry.

In accordance with this plan, after the silt had been removed from the greater part of the site of the lock, an incline was made from the river embankment down to the east end of the lock; and by the end of July, 1866, a cutting had been effected throughout its entire length on the level of the upper surface of the bottom clay, which was found to dip gradually from west to east. The bed of sand proved much thinner than had been anticipated, varying from 2 feet to 3 feet, but passing in many places into potholes in the clay. At the east end of the lock, where it was expected that the sand-bed would be of greater thickness, the potholes were more numerous, but in no case was it continuously of the thickness indicated by the borings.

In the month of September 1866, when the excavation was far advanced and a great part of the surface of the bottom clay had been laid bare at the east end of the lock, further progress was prevented by the appearance of two springs or 'boils' near the line of sheet piling, which had been driven at this date from the return wall about halfway across the lock entrance. The water from these boils, which was brackish and charged with yellow sand, soon mastered the hand-pumps, which were fixed to clear the foundation of water, and necessitated the abandonment of the east end of the lock. A stank was made across the gullet on the site of the east sill to confine the water to that end of the lock. This

stank was barely finished before the breach in the river bank occurred, which afforded the waters of the Humber free access to the lockpit for nearly four weeks; and though the breach was repaired in that time, three months elapsed before work could be resumed.

Soon after the boils started, and prior to the breach in the river bank, a crack appeared in the shore piece of the North Basin wall against which the cofferdam abutted on the north side of the lock entrance. Fear was entertained lest the water from the basin should have found a passage beneath this wall, of which the part nearest the basin was built on bearing piles, and the remainder near the lock on concrete resting on the lower bed of clay. That this might be the case appeared likely from the fact that the crack divided the wall vertically near the point where the change in the plan of the foundations occurred. It was thought possible, at one time, that the crack might be caused by the pressure from the cofferdam at high water. That this was not the case was shown by the change in width in the crack. At high water the crack was scarcely visible, whilst during low water, when the pressure from the dam was least, it increased to the extent of 1 inch in width. As any further settlement in this wall might have endangered the safety of the dam, the two portions into which the wall was divided by the fissure were connected by four wrought-iron tie rods, 2 inches in diameter, which were secured to the finished portion of the wall adjoining the Railway Creek by lewis bolts, and passed through baulks placed across the unfinished end of the wall. No other change occurred in this wall during the progress of the work.

For the further protection of this side of the lock a dam, *x y* (Plate 8), was driven from the North Basin wall eastwards parallel to the Railway Creek. This dam, which was begun on the 23rd of November, 1866, consisted, for the first 80 feet west of the return wall, of two rows of sawn piles 13 inches square and 5 feet apart, and for the remaining distance, about 300 feet, of a single row of sawn piles averaging 47 feet long, and extending to a depth of 55 feet below coping level. It was connected throughout its whole length with the wharfing of the Railway Creek by iron tie-bars from 1½ inch to 2 inches in diameter carried through the bank at a depth of 2 feet or 3 feet below the surface, and at distances of about 30 feet apart. A single row of piles was also driven across the angle formed by the large semicircular dam and the return wall.

The breach occurred in the river bank on the 17th of September,

1866, and the above-mentioned dam was nearly completed before the water had been sufficiently lowered in the lockpit to admit of work being resumed there. By the 11th of December the water was lowered to such an extent as to admit of a piling engine being got to work at the row of sheet piling across the lock entrance, which was extended to the back of the south lock wall, and a row was also driven along the back of that wall for a distance of 110 feet. It was considered the more necessary at this time to inclose the east end of the lock with sheet piling, as no fixed conclusion had been arrived at as to the immediate source of the boils. This proved eventually to be far more deep-seated than it was assumed to be at first, and in no way connected with the superficial strata through which the piling hitherto driven had penetrated.

After the water had been pumped out of the lockpit, the part excavated for the foundations was found to be filled with mud to the height of sill-level, or to 23 feet above the rails of the lower wagon road. Much of this mud was raised to the level of the top of the river bank by a large chain pump, for some time in course of erection, but which was not completed until the 11th of February, 1867.

To assist in removing the mud, a 6-inch syphon was laid over the cofferdam, and by the water from this source combining with it, a continuous stream of liquid mud was kept flowing to the chain pump. The drier material was removed by swing and horse roads on both sides of the lock, and wagons were also worked down the old incline at the west end along the surface of the upper bed of clay on the north side of the lock. At the east end of the lock there was laid bare a large bed of sand, deposited by the water flowing from the boils, which as yet gave no signs of activity.

On the 11th of February the dam parallel to the Railway Creek showed symptoms of yielding. As there were no means of strutting this dam from the lock side, all the lower part of the excavation being still filled with a depth of from 10 feet to 15 feet of mud, preparations were made to drive a row of sheet piles along the back of the north wall, at a distance of 20 feet from the foot of the dam, and also two rows across the lock at distances of 74 feet and 144 feet respectively from the row already driven at the entrance.

On the 3rd of March, before much progress had been made with this piling, a boil appeared not far from the centre line of the lock, and near the site of the east sill. A circular rim of sand about 5 feet in diameter first rose above the surface of the mud

and water, in the centre of which a hole extended to a depth of 16 feet. A pile 25 feet long was driven into the centre of this boil, and disappeared below the surface of the water after a few blows.

On the 9th of March the signs of failing in the dam, *x y* (Plate 8), became more evident. Several of the iron tie-bars broke in succession, and on being replaced by fresh ones as fast as they could be procured, the timber gave way along a line about 20 feet below the pile-heads. Owing to the settlement which was taking place, the machinery of the mortar mills, was thrown out of gearing, and numerous cracks appeared in the bank between the dam and creek. This bank was reduced and the slope behind the dam lightened to as great an extent as was deemed consistent with its efficiency; and by this means, and with the assistance of struts from the piles already driven in the lock, the movement in the dam was so far arrested as to allay the fears for the safety of the bank.

An event occurred about this time which threw some light on the origin of the eruptions. It has been already remarked that the water from the boils was charged with clean yellow sand. The only sand which had been found by boring or otherwise in the lockpit was that composing the thin bed dividing the two clays, and this was grey, loamy, and passing into small gravel in places. A boring in the neighbourhood of the lock extending to the surface of the chalk, which was reached at 109 feet below quay-level, passed through a bed of sand overlying that formation. The great depth of this bed below the surface and the thickness of the overlying clay seemed to preclude the possibility of the boils being connected with it. To ascertain the nature of the strata underlying the lockpit, a series of borings were taken in three parallel lines, along the centre line of the lock and along the centre lines of the walls. The borings were 25 feet apart, and extended to 65 feet below coping. Solid homogeneous brown clay was met with in every case for the lower 10 feet of these borings. The borings were made with a common auger, 1 inch in diameter, and without pipes, excepting in places where the mud had not yet been removed from the surface. On the 11th of March the water boiled up the fourth bore-hole from the piling at the lock entrance on the line of the north wall, charged with yellow sand similar to that brought up by the former boils. After this occurrence it seemed probable that the boils had their source below the lower bed of clay. To set the matter at rest, a 3-inch boring was made through this bed. The boring was begun at a depth of 43 feet below coping,

and a thickness of 40 feet of solid brown clay was penetrated. This clay was free from water, and the bore-hole remained dry until the bottom of the bed was reached, when water charged with yellow sand flowed up the hole with considerable force. The water was allowed to rise in a vertical pipe connected with the bore-hole, and ceased to flow at a height of 11 feet above sill-level, or 24 feet below coping. That the boils had their source in the sand-bed resting on the chalk seemed proved beyond doubt. This latter formation dips from the foot of the wolds in the direction of Hull at the rate of about 16 feet per mile. As the chalk wolds, extending over a large area, attain an elevation of 500 feet at no great distance from Hull, and give rise to copious springs at their base, these boils were possibly as much due to land water accumulated in the chalk as to any connection of the sand-bed with the Humber. That some such connection, however, did exist is probable, as the water was brackish.

On the 15th of March a third boil appeared, and four days later a fourth. In consequence of the quantity of sand brought up by these spouts, the ground began to settle on the north and south sides and east end of the lock. A crack appeared on the top of the river bank, about 30 feet from and parallel to the line of the river wharfing, and extended eventually 400 feet in length. That part of the bank between the crack and the lock subsided vertically to the extent of 10 feet and 12 feet in some places. The settlement was gradual, and the maximum was not reached until the foundations of the lock had been made comparatively secure several months after the first appearance of the crack.

To strengthen the bank on the river side, clay was tipped outside the river wharfing from a wagon road laid for the purpose. Mounds of clay, about 10 feet high, were also formed round the third and fourth boils, and by this means the quantity of sand flowing from them was much reduced. The first boil had stopped, and was replaced by a fifth, which appeared on the westernmost cross row of piling, and nearer than any of the former to the chain pump, into which it poured such a large quantity of sand that a bank 6 feet high was soon formed in the river, near the place where the water was discharged from the pump. This boil, which was one of the worst, suddenly stopped, and reappeared 10 feet to the east of the piling. In this position the boil continued to flow until the end of August, four months after its first appearance.

In addition to the two rows of piles already driven across the lock, two more were driven parallel to the centre line of the lock, dividing the east end into six compartments. It was

determined to leave those in which the boils were until the last. In the compartments free from them, the sand, peat, or mud was removed over an area of about 4 yards square, divided from the remaining area by sawn planks 5 inches or 6 inches wide, driven by hand. When a bottom of hard clay had been found, the clay being either of the upper or lower bed, the space was filled with concrete. It may appear that the order of taking the compartments should have been reversed, and that those in which the boils were situated should have been dealt with first; but boils had appeared in all the compartments, and, without doubt, if the boil were stopped in one compartment before that adjoining it were made good, it would have reappeared in the latter place, and two would have required dealing with instead of one. It was found that although considerable time was always required to clear out an old vent, by limiting the area to be excavated and using every despatch, the concrete could be carried over the site of an old boil to a depth of 10 feet or 15 feet beyond the point to which it had been necessary to heap up the clay in order to check the flow of water. Sections of old bore-holes were exposed in the foundations, choked up with fine gravel or sand; but time was not allowed for the water to clear out these vents, though within a distance of a few yards it was rising from the same strata with which the bore-hole communicated to a height of 15 feet above the bottom of the foundation. The compartments on the north side of the lock were filled with concrete without accident; and all went well with those on the south side until the last length to the westward was being excavated, when a boil burst up by the side of the second cross row of piling. A stank about 4 feet square was formed round this boil by driving 4-inch sawn planks on three sides, the piling forming the fourth side. The concreting was then completed in this compartment with the exception of the part surrounded by the stank, round which clay was heaped to check the flow of water. In order to facilitate the excavation of the easternmost of the centre compartments, two rows of sheet piling were driven across it at right angles to the centre line of the lock, dividing it into three spaces, 15 feet, 40 feet, and 18 feet wide respectively, the latter being to the westward and partly underlying the sill. The space to the eastward was first excavated to a depth of 13½ feet below the sill-level and filled with concrete. In the centre beneath the apron, no attempt was made to reach the clay, as the whole of the upper bed had been removed, and it would have required the excavation to be carried to a depth of 20 feet below the sill-level to reach the surface

of the lower bed of clay; accordingly the concrete was carried to a depth of 10 feet only below sill-level. In the third compartment, which would form the foundation of the back part of the sill, the bottom bed of clay was reached over one-third of the area, and the old rails of one of the wagon roads were found at a depth of 19 feet below the sill-level. In the remaining part of this space the excavation was carried to the same depth, but the clay bottom was not found, nor was there any trace of the wagon road which had passed over this spot. The bottom consisted of a quicksand, which could be penetrated with a bar to a depth of 8 feet. During the night this excavation was filled with concrete to a height of 11 feet above the bottom. A boil started shortly after the concreting was begun, and filled the foundation with water, which continued to rise through a thickness of 11 feet of concrete. The hand-pumps had been quite inadequate to remove the water which flowed into this foundation, and much of the concrete was impaired, the water having washed the lime out of it. The removal of the concrete was not attempted until two small chain pumps had been made, each capable of lifting 800 gallons of water per minute. These pumps probably answered better than any other class of pump would have done under the circumstances, and were able to lift much of the sand brought up by the boils; but they were occasionally stopped by gravel washed out of the concrete. Much of this latter material, however, as well as pieces of chalk and brick, were lifted from time to time without impeding the working of the pumps. After one of these pumps had been fixed in the foundation, the imperfect concrete was removed for a depth of 5 feet, and the flow of water, which had become very strong, was confined to two places by concrete made of Medina cement. This was lowered into the foundation in a box containing 1 cubic yard. An old millstone with a hole in the centre, which happened to be at hand, was set over one of these vents in a good bed of Medina cement, and though some difficulty was experienced in forcing the water up the hole, this was eventually done. A hole was made in a second stone, which was in like manner set over the second vent. The holes were afterwards plugged up, but not before great trouble had been experienced with this length of foundation, as the water found its way up in many places through the ordinary lime concrete. The concrete of Medina cement would not withstand the action of running water, and small orifices in it soon became enlarged. This cement was for the future only used in small quantities in wet places and when covered up with Portland cement. After the wooden plugs were driven into the holes in the stones,

so great was the pressure of the water below that it oozed up through many spots in the neighbourhood. Much trouble was experienced on the east side of this foundation, where two large and several smaller boils had to be confined to holes in stones surrounded by brickwork set in Portland cement.

Of the six compartments into which the east end of the lock had been divided, one only now remained, of which the greater part lay beneath the east sill. No attempt was made to reach the lower bed of clay, 20 feet below sill-level. Sir John Hawkshaw decided that a bed of 6 feet of concrete below the bottom of the masonry of the sill would be sufficient. As the masonry would be 9 feet thick, this gave a depth of 15 feet below the sill-level for the bottom of the foundation. The compartment had already been divided into two nearly equal spaces by a row of piles 16 feet long, driven at right angles to the line of lock, and the easternmost of these spaces was again divided by a row of sawn 4-inch planks driven in the same direction.

It was decided to substitute brickwork for concrete in this compartment, for the following reasons:—when the bottom of the foundation was of sand, boils had on more than one occasion broken out soon after the concreting began; and it was believed that the fall of the concrete from the barrows on the sandy bottom, which thereby assumed the nature of a quicksand, accelerated their appearance. Moreover, by adopting brickwork, as soon as the requisite depth had been obtained over a small part of the area to be excavated, this portion could at once be made secure; whilst, on the other hand, the bottom could not be made secure with concrete until an area of considerable extent had been excavated to the required depth.

In the two areas divided by the sawn planking, the following plan was adopted:—as soon as a space about 3 yards square had been reduced to the required depth, a flagstone 5 feet square was set in a bed of concrete made with Medina cement, the upper surface of the flag being level with the bottom of the foundation. On the centre of this flag a small chain pump was placed, and four courses of brickwork, set in Portland cement, were laid over the bottom of the foundation as fast as it could be excavated, the brickwork overlapping the flag and forming a well-hole for the pump, from which also a channel about 1 foot wide, with a bottom of flagstones, was left up the centre of the foundation, so that in the event of a boil bursting out, the foundations could be drained to the lowest level required, whilst the pump hole remained secure and available to the last. The eastern half of the sixth compartment was thus

covered with four courses of brickwork; the pump was then removed, and the foundation levelled with a layer of concrete made with Portland cement 1 foot thick. In the western division of this same compartment a boil, which was still in an active state, was first surrounded on three sides by 4-inch planking, driven by a small hand-engine. With the exception of the space, 33 feet by 7 feet, so inclosed, this division was dealt with in the same manner as the last.

To overcome the larger boils, some castings had been made which it was thought would be an improvement on the stones perforated as described above. These castings were in the form of a hemispherical shell, 3 feet in diameter at the base, and with a circular opening 6 inches in diameter at the top, continued in the form of a pipe terminating in a flange, to which 6-inch piping could be bolted, room being left for the nuts between the lower surface of the flange and the shell. As the excavation was proceeded with in the neighbourhood of the boil within the stank formed by the planking, the flow of water and the quantity of sand accompanying it increased very much, and it was necessary to keep two chain pumps at work to remove the water. A length of 9 feet of 6-inch pipe, bolted to one of the castings just described, was then lowered into the funnel-shaped cavity from which the water flowed; the casting sank until the top of the pipe was just level with the water. The space within the planking was next filled with concrete to within 1 foot of the top of the pipe. If the diameter of the pipe had been larger, the whole of the water would probably have flowed up it, and the concrete would have been sound; as it was, the pipe could not take all the water, which at one time rose in a jet 2 feet high, and much water still flowed through the concrete. The injured concrete in the vicinity of the pipe was covered with brickwork set in Portland cement, space being left between the bricks for the escape of the water flowing from the concrete. This water was gradually collected into one channel, and conducted through a 6-inch pipe 9 feet long laid horizontally and set in bricks and cement; but the combined capacity of the pipes was not sufficient at the time of high tide to take all the water, which found outlets through several weak places in the brickwork and concrete. Two chain pumps were kept constantly at work during the time of high tide; on one of these breaking down during the night, it was quickly sanded up. About 20 cubic yards of clean sand were deposited in the foundation in the course of twelve hours. Short lengths were added to the vertical pipe until the total length above the casting

amounted to 22 feet. The top of the upper length terminated at sill-level; at this height the water still flowed, but gradually diminished in quantity, latterly bringing up fine mud instead of sand. When the water ceased to flow, which it did sooner, probably, from boils having broken out in the cutting to the westward, the pipe was filled with Portland cement; and the horizontal pipe was with difficulty plugged up at the low level.

During the time occupied in forming the foundations to the extent just described at the east end of the lock, the cutting throughout the remaining portion had been gradually re-excavated and filled with concrete. A row of sheet piling had been driven along the south side to sustain the river bank, but as the upper clay had not been removed on the north side, the cofferdam piling was then considered sufficient. The concrete had been placed on the bottom clay when the upper bed had been removed, excepting for about 50 feet west of the row of piles bounding the compartments. The piles forming this row, of which the tops had been cut off at a uniform level of 4 feet 6 inches below the sill-level, had settled, especially towards the south side and centre of the lock, to the extent in the latter place of 5 feet. As the bottom clay had also sunk, the sand and silt overlying it were only removed to a depth of from 47 feet to 49 feet below quay-level, and the concreting proceeded with. The foundations at this part gave much trouble, and several boils were dealt with. Two of the castings above described were used, to which lengths of horizontal pipes 9 feet long were bolted. This addition was a great improvement, as the site of the boil could, on the casting being placed over it, at once be covered with concrete, and by means of an elbow subsequently bolted to the horizontal pipe, the outlet could be gradually raised vertically by short lengths of pipe as the concreting was proceeded with. When a vertical pipe had been used directly over the casting, it had been found that the water almost invariably came up through the fresh concrete surrounding the casting. For, as the surface of the concrete had to be kept at least 1 foot below the top of the pipe, in order to leave room to bolt on additional lengths of vertical piping, the water in finding a vent through the concrete had less height to rise than would have been the case if it had flowed up the pipe. Another obvious advantage in using the horizontal pipe was the removal of the flow of water to a distance from the concrete. A canvas hose had been tried for this purpose, but the first objection to the vertical pipe applied equally to it.

Four vertical pipes, 6 inches in diameter, were brought up in

the concrete west of the compartments. When the concrete round these pipes had set, additional lengths were bolted to them until the top of the pipe exceeded the level above which the water would rise. As much Portland cement grout as they would hold was then poured into them.

Two of the pipes were thus filled on the 26th and 29th of August, 1867, and the remaining two at the end of September. In order to get as much concrete over the last end of the lock foundations as possible, a wall about 4 feet high of brick, set in cement, was built round the space where the concrete had to be left at a low level to receive the deep stones of the east sill. The space thus inclosed was 100 feet by 48 feet. The remaining part of the foundation was filled with concrete to the level of the top of the wall, excepting the part beneath the gate-floor, which was left 2 feet lower. The water was then allowed to rise over the low portion. When the water was pumped out again on October the 5th, it was found that a slight settlement had taken place, that the concrete forming the foundation for the sill and gate-floor was cracked, and that water was coming up in several places. The Author thereupon decided to cover the site of the sill and gate-floor with a bed of 18 inches of concrete made of sand, gravel, and Portland cement, and to reduce the depth of masonry to the same extent. Where the greatest settlement had taken place in the foundation for the sill a hole for a pump was made. The bottom consisted of a flag about 5 feet square, on which a well-hole was built of brickwork set in cement.

It had hitherto been found quite useless to attempt to stop even small boils with concrete alone; accordingly, where a boil now occurred in the concrete, a shaft of brickwork set in cement was built over it, an opening for the escape of the water being left on the side nearest the pump. From this opening a narrow channel was formed by two brick walls extending in the direction of the pump, to a distance from the shaft depending on the size of the boil and the more or less perfect state of the concrete. On the top of the shaft was placed a stone with a hole in the centre. The top of the stone was set even with the finished level of the cement concrete, which was then put round the brickwork. When this concrete was consolidated the narrow channel between the brick walls was also filled, and the water forced up through the hole in the stone. The water flowing through the concrete in the sill was thus confined to five places. Owing to settlement which was still going on, an unforeseen difficulty occurred at the pump-hole. The lime concrete parted from the more rigid

layer of cement concrete above it, and with it the lower part of the pump-hole. Through the crack thus formed in the walls of the pump-hole the water found a vent. To remedy this a wall of brickwork, set in cement, was built round the well-hole of the pump to a height beyond which the water would not rise. The space so inclosed was then filled with concrete; the holes in the stones were stopped with wooden plugs; but the plan which, of necessity, had been adopted for the pump-hole, and also previously for the cast-iron pipes, was found to be much preferable. When plugs were used the water was left with a free communication to a point too near the surface, and consequently when the concrete had been formed to the different levels, and the lower settled away from the upper layer, the brick shafts were divided below the plugs, and the water escaped from between the layers.

The boils in the gate-floor were treated in the same way as those in the sill. On the 20th of November all was made good, and the flow of water reduced to an insignificant quantity, for the first time since the boils appeared on the 3rd of March. A stank was placed across the masonry of the invert, at this time partially built to within 200 feet of the east sill, and the water was allowed to accumulate at the east end of the lock until it attained a level of 2 feet above the sill. On the 27th of November the water was pumped out, and a strong boil was found to have burst up through the cement concrete in the sill, where further settlement had taken place. A wall of brickwork, set in cement, was built round this boil, inclosing a space of about 4 feet square. On the 11th of December it was determined to remove the east sill 190 feet to the westward, and to cover the abandoned site of the sill, gate-floor, and apron with brickwork set in cement to within 2 feet of sill-level. This was accordingly done, the brickwork was continued beneath the lock walls at the same level, and a portion of the back of the lock walls, to a height of 12 feet, was also built of brickwork, set in lias lime mortar. This brickwork effectually stopped all flow of water. The space behind the lock walls was at once backed up, and the difficulties with these foundations seemed to be finally overcome. The last boil had been allowed to run for some time after the brickwork was completed, the walls round it were gradually raised until they reached a level of 10 feet above sill-level, and the water having ceased to flow, the inclosed space was filled with concrete.

The concrete on the new site of the east sill had been formed to a level of 6 feet below the sill to receive the invert. To avoid removing so large a quantity as would otherwise have been

necessary, the masonry of the sill was reduced in depth from 9 feet to 6 feet. A trench, however, 12 feet wide and 3½ feet deep, was cut in this concrete, extending beneath the edge of the sill to the back of the walls on each side of the lock, and was filled with brickwork in cement. Part of the masonry of the west sill had been set before it was found necessary to alter the position of the sills. This masonry was lifted and a new foundation formed 110 feet to the westward, the lock being thus reduced in length from 400 feet to 320 feet. For this foundation the upper bed of clay was excavated to a depth of 12½ feet below the sill-level, to admit of a layer of concrete 2½ feet in depth beneath the masonry. The concrete was formed of broken whinstone, gravel, sand, and Portland cement. The whinstone, which is largely used for road metalling in the East Riding of Yorkshire, was obtained from a dyke near Whitby. The layer of concrete was extended as far as the back of the walls on each side of the lock.

Beneath the west apron of the lock a culvert was built of brickwork set in Portland cement, to connect the water, gas, and other pipes on the north and south sides of the lock. In reaching the depth required for the foundations of the culvert, the upper bed of clay was cut through, as was also the bed of sand dividing the two clays. A layer of concrete, 18 inches thick, of Portland cement, gravel, and sand, was placed on the clay, and on this the culvert was built and surrounded on all sides by concrete, 1 foot thick, of the same composition. On the water being let into the dock this culvert gradually filled, and the water rose in the shafts to the level of that in the dock. When the water was pumped out of the culvert, in order to lay the pipes under the lock, no leak was perceptible in the brickwork, but a general infiltration through the whole of the brickwork, which was constantly wet, made some pumping with a hand-pump necessary each day in order to keep the water down.

After the position of the east sill was moved 190 feet to the westward, a second invert was placed to the east of it on the concrete which had already been prepared to receive the invert between the two sills. Eastward of this second invert, the brickwork set in Portland cement over the abandoned site of the east sill and the apron was covered with a layer of concrete, 2 feet in thickness, of gravel, sand, and Portland cement, in the proportions of 3, 2, and 1 respectively. Great pains were taken to get a good surface on this concrete, and to avoid imperfect junctions when fresh concrete overlapped that which had already set. The difficulty of making these junctions perfect forms one of the

principal drawbacks to the substitution of concrete of Portland cement in extensive layers for masonry. When by proper attention to the work such imperfections can be avoided, the Author believes that aprons, gate-floors and sills may be most economically made of this material.

After the lock walls were built and backed up, a slight settlement took place at the east end of the lock; for a crack about $\frac{1}{8}$ inch wide appeared along the centre of the apron, and one or two of the joints of the east invert opened perceptibly as far as the back of the sill. No cracks appeared in the walls, nor have the levels appreciably altered up to the present time.

The River and Dock Pitching. (Plate 9.)

It will not at first be apparent why a part of the embankment fronting the Humber was faced with timberwork, and the remaining part with stone pitching. It has already been remarked that the timber wharfing extended along the river front as far as the western limit of the dock which it was proposed to construct under powers granted by the Act of 1861. By forming the river frontage of timber the whole of the area acquired under this Act was rendered available for dock purposes. When the dock works were extended under the later Acts, the great increase in the width and length of the quays made the loss of the space which would be occupied by the pitching of less consequence, and the more durable protection which it affords was therefore adopted.

The pitching of the river bank was of stone from Horsforth quarry, 18 inches thick, laid at a slope of 2 to 1 on broken chalk. A layer of large blocks of chalk about 2 feet thick had been placed on the slope of the embankment, to protect it while in progress, and the upper part of this chalk was broken small to receive the pitching. The dock bank was covered with stone from the same quarry, 18 inches thick, laid at a slope of $1\frac{1}{4}$ to 1 on the surface of the ground. Where the toe of the pitching was in sand it was supported by close piling 12 inches thick and $9\frac{1}{2}$ feet deep. When the bed of sand rose above the dock-floor, part was excavated and replaced by concrete as high as the bottom of the upper clay, which generally formed the lower part of the slope. If the sand thinned out, and the clay extended below the bottom of the dock, the slope was continued to a depth of 3 feet below that level. In some places where the bank was of sand or silt the pitching was laid on broken chalk, varying from 6 inches to 3 feet thick.

The slope at the end of the dock was covered with pitching 12 inches thick, laid on broken chalk 6 inches thick, at a slope of 3 to 1. The pitching on this slope only extended to a depth of 3 feet below the level of high water of neap tides.

Lock Gates and Hydraulic Machinery.

The lock gates were made from Sir John Hawkshaw's designs, at the Elswick Engine-works, Newcastle-on-Tyne, by Messrs. Sir W. G. Armstrong and Company. They were of wrought iron, with heel post, mitre post, and sill pieces of greenheart.

The gates are worked by hydraulic machinery. The whole of the hydraulic machinery, the coal drops, cranes, capstans and swing bridge were supplied by Messrs. Sir W. G. Armstrong and Company, and were erected under the superintendence of Mr. C. Wawn, Assoc. Inst. C.E. The hydraulic machinery was generally similar to that used in many of the docks in this country.

The communication is accompanied by a series of drawings and diagrams from which Plates 8, 9, and 10 have been compiled.

Appendix.

APPENDIX.

THE ALBERT DOCK AT KINGSTON-UPON-HULL.

Total Cost of the Works.

	£.
Excavation	113,592
Dock walls and dock slopes (including the cost of jetties and mooring rings, and all masonry, timber, concrete, and excavation for foundations below the level of dock bottom)	118,680
Basin wall (masonry, timber, concrete, and sluices)	20,778
Lock (masonry, timber, concrete, and excavation for foundations below the level of dock bottom)	88,655
River front and creek (timber wharfing, pitching, and chalk deposit)	102,074
Cofferdam (for lock and basin walls)	34,926
Ballast for quays and for permanent way	7,415
Engine, boiler, and accumulator; house foundations for swing bridge and hydraulic machinery (masonry, timber, excavations and brickwork)	8,343
Diversion of sewers	21,736
Lock gates, swing bridge, coal drops, capstans, and hydraulic machinery	37,027
Permanent way	6,253
	£559,479

Cost of dock walls (5,307 lineal feet) per foot run, including excavation for foundations below the level of the dock bottom, £19 9*s*.

Quantities of Material, etc.

Granite	34,396 cubic feet.
Ashlar of Bramley Fall	310,729 " "
Rubble masonry of Bramley Fall	117,585 cubic yards.
Brickwork	10,300 " "
Pitching of Bramley Fall	29,000 square yards.
Timber in cofferdam	150,000 cubic feet.
Timber in permanent work	501,000 " "
Chalk	118,000 tons.
Concrete	66,400 cubic yards.

[Mr. Harrison,

Mr. HARRISON, President, said he had frequently seen the works when in course of construction, and he regarded them as among the most interesting engineering works that had come under his observation.

Sir WM. WRIGHT observed that the difficulties explained so ably by Mr. Hawkshaw were of an engineering kind, and it was a most pleasant thing, now that they were past and overcome, to have them discussed, affording as they did encouragement to young aspirants in their efforts to vanquish similar obstacles in works in which they might be engaged. But he was unfortunately tongue-tied with regard to the financial difficulties encountered by the promoters of the undertaking, who often to a painful extent shared the feelings which Sir John Hawkshaw had sometimes expressed in reference to the works. He was happy to say that these too had been overcome. He well remembered standing on the works and seeing the tremendous boils coming no one knew whence. The more they were probed the worse they became. The possibility of the failure of the works was at one time anticipated; but there were engineers present who had been able to carry them out and bring them to a satisfactory conclusion, so that a boil was now regarded as entirely a thing of the past.

Sir JOHN HAWKSHAW, Past-President, said the difficulty that occurred at the lock was not easy to understand from the drawings, and its nature might be better understood by a few verbal observations. From 15 to 20 feet from the surface was made-ground, rubbish thrown there from time to time; then came a bed of sand, resting on a bed of clay of the most compact description, and then another bed of sand resting on chalk. This was ascertained by borings. Before the work was commenced many borings were made into the clay, deep enough to ascertain that it was sufficiently thick to form a good foundation for the lock. He had one boring taken through the upper strata to the chalk, which was found to be from 95 to 100 feet below the surface. The bed of clay at that place was 40 feet thick. When the lock was designed the intention was to remove the loose material and the upper bed of sand, and to found the lock upon the surface of the bed of clay. The excavation had nearly reached the surface of the clay when the irruption through the river embankment took place. The water, however, was got out, and the excavation continued. After a time, at the east end of the lock especially, boils showed themselves. They came up with great force, and spread in various directions. For a considerable time it was apprehended that the origin of the boils was the water finding its way out of the Humber, under the

cofferdam into the upper bed of sand. Attempts were made to stop the boils, and other works were executed to strengthen the dam. So serious did the matter at one time appear, as it was uncertain what the depth of the sand might be where the cofferdam had been driven, that he began to fear there might be no way of completing the foundation, but by letting the water rise, cleaning off the surface of the clay by dredging, putting the concrete through the water, and so making the foundation of the lock in water. He had prepared a sufficient amount of broken whinstone, and small dredgers for the work. His son about this period suggested that the boils must come from below the bed of the clay. This appeared somewhat startling; but there was the fact that, whereas the sand above the clay was grey, the discharge brought up was of a yellow colour, tinged with red. He had noticed this peculiarity, but had thought that possibly the water had become impregnated with iron, and had thus dyed the sand. He resolved to ascertain the fact by going to a place about halfway along the lock where the clay was exposed, and boring through it. The boring passed through 40 feet of solid clay; no water came until the chalk was reached, when it immediately rose 11 feet above the surface. That, of course, set the matter at rest; and then the question arose how the boils could come from below so thick a mass of clay. It was ascertained that there had been numerous borings through the clay at this spot on former occasions, both by Mr. James Walker, and by persons who proposed to construct baths and wash-houses. There had, in fact, been three or four sets of borings before he had anything to do with it, so that the clay was perforated in numerous places. In carrying out the works, many of the bore-holes were found filled with fine white chalk; others had been cleared out by the great pressure, which led to the appearance of the various outbursts, requiring the complicated arrangement described in the Paper to stop them. To show the extent to which the bed of clay was ultimately undermined by the water bringing up sand, he might mention that the rows of piles driven across the lock and the bed of solid clay into which they were driven settled down 6 feet to 7 feet. With regard to the irruption through the river embankment, it might be interesting to mention the way in which it occurred. The foundations, at that place in fine sand, were excavated about 17 feet deep. The wall had been carried on in that manner successfully up to the time when the irruption took place. A further length of foundation was excavated. The concrete was not got in rapidly from some cause or other, and it was left standing for a short time. The

water appeared to have found its way under the base of the embankment, through the sand, into the length of foundation, carrying the sand with it. It rose up into the inclosed area, and ran with such violence, and excavated the sand under the embankment so rapidly, that the embankment settled down and admitted the water over the top.

Mr. A. GILES congratulated Mr. Hawkshaw on the moral courage he had exhibited in not only giving a history of the dock, but of the difficulties encountered, and the means adopted to remedy them. The work had evidently been one of unusual difficulty. It was certain that, but for the peculiarities of the site, Sir John Hawkshaw would have made the dock wider in proportion to its length. He was, no doubt, as much limited by the width of the foreshore in putting the dam where he did as he was in making the dock so narrow. Sir John Hawkshaw had anticipated a remark which he was about to make, namely, that difficulties often arose from unnecessary borings, and that where it was really necessary to make a deep boring it should be as far off as possible from the difficult part of the work. He had no doubt that the yellow sand was laid bare in the bed of the Humber, and, when tapped by boring, it would rise almost to the height of high water. He should have been glad if a little more detailed information had been given as to the cost. He thought that 300 feet was hardly sufficient length for a lock 80 feet wide. When Sir William Wright described the opening of a dock nearly a hundred years ago, he referred to locks 150 feet long and 40 or 50 feet wide. That was a measurement well enough adapted to old times; but modern ships could scarcely use those docks. Even the "Bessemer," which was 350 feet long, could not get into this new lock. He had heard it stated that an arched wall was rather more expensive than a solid wall. It was now the habit to make solid walls of concrete, with a brick or stone face, and he thought they were more substantial than hollow walls, and less costly.

Mr. J. CLARKE HAWKSHAW said the total cost of the Albert Dock at Hull was, in round numbers, £560,000. (Vide Appendix, p. 113.) This included £22,000 for the diversion of the sewers, £37,000 for the gates, swing bridge, coal drops, capstans, and hydraulic machinery, and £6,000 for permanent way. The cost of the dock per acre was £24,300, and that of the wall, including excavation below dock floor level, mooring rings, ashlar for mooring rings, and all other extras, just under £20 per lineal foot for over 5,000 feet of wall. Without these extras, which were not generally included in calculating the cost per lineal foot, the result would be about £18 per foot. The

cost of the dock also included the charge for reclamation of about 70 acres of land.

Mr. REDMAN said the Chairman of the Dock Company had classed Hull as the third port of the kingdom. Perhaps in some respects it might be so classed, but if the aggregate foreign and colonial tonnage was considered the test, it would be found that, in 1873, Hull was only the fifth. The returns for that year showed a tonnage of 8½ millions for Liverpool, 8¼ millions for London, 3¾ millions for Newcastle, and, including North and South Shields, 4¾ millions; 2¾ millions for Cardiff, 2½ millions for Hull, 1⅝ million for Southampton, 1½ million for Sunderland, and 1⅛ million for Glasgow. It was remarkable that the commencement of dock enterprise was almost simultaneous in Liverpool, London, and Hull. A comparison of the plans which accompanied Mr. Timperley's "Account of the Harbour and Docks at Kingston-upon-Hull,"[1] with the drawings illustrating the present communication, showed the vast amount of piling used in the early dock-works, and the comparative absence of piling in modern ones. This was apparently due to the greater depth to which the piling was now carried. In the former case a large amount of silt had to be penetrated by piling; but a great deal of the silt had since been removed. Another reason for the difference was the general use of the improved concrete of the present day. The plans for the Garrison Dock (or as it was now termed, the Victoria Dock) were originally designed and deposited by Mr. James Walker, Past-President, C.E. That Act was not carried without considerable opposition. The owners of property along the river Hull brought forward a counter-scheme for turning the river into a dock, and diverting it along the course of what was now the new dock, the late Mr. Rendel, Past-President Inst. C.E., being then Engineer. The great feature of interest in practically carrying out the works described by Mr. Hawkshaw was the difficulty due to the peculiarity of the stratification of the ground—silt 30 feet thick overlying a seam of 30 feet or 40 feet of stiff clay and pebbles, and under that a layer of 30 feet or 40 feet of quicksand above the chalk. There could be no doubt that the results so frankly stated, and so ingeniously overcome were caused by the bore-holes tapping the intermediate seam of stiff clay. Mr. Stead in 1838 made a boring 120 feet to 130 feet deep, down to the chalk, and recorded that at that period this was the deepest boring at

[1] *Vide* Transactions Inst. C.E. (4to.), vol. i., p. 1.

Kingston-upon-Hull, a statement in accordance with the statistics given in the Paper. With regard to the enormous amount of water with sand brought up from the lower stratum, in many such cases the error was committed of endeavouring to overcome the difficulty by force, instead of leading the water away to the pumping station. In the present instance, however, there was the contingent difficulty that as the water was pumped away the sand was drawn with it. It occurred to him that if, instead of leading the water away, it had been raised to the level of the head supply, which in this case must have been the surface of the water of the estuary of the Humber, the difficulty to a certain extent would have been conquered. It might have been done by erecting over one particular boil a stand-pipe which should maintain a constant head of water. At the present time dock accommodation was not commensurate with the opportunities which the different ports afforded for such works, and the Institution was much indebted to Mr. Hawkshaw for the description of the peculiar difficulties overcome in carrying out this important work.

Mr. Grant said that, in carrying out the main drainage works on the south side of the Thames, the same sort of fine sand was found overlying the chalk, and on more than one occasion circumstances arose similar to those which were met with at Hull. He was not familiar with Hull, and therefore could not say whether or not the means adopted in the main drainage works would have been applicable there. His method of overcoming the difficulty was to sink a well outside the work below the lowest level of the foundation. In sinking the wells for this purpose it was important that pumping should be avoided; after a sufficient depth had been attained, the sand which it was desirable to avoid drawing off should be loaded with several feet of gravel to act as a filter, so that when the pumping was commenced the sand might not be brought up. By such means he prevented cavities from being formed under the work and under the adjoining houses. The plan was perfectly successful. In one case when passing through Woolwich, at a depth of 60 feet or 70 feet, an overpowering spring of water suddenly appeared. A sump was made outside the work, and the water drawn downwards, and immediately that was done operations were continued as before. In the case of the pumping stations, where the excavations were deeper than elsewhere, the plan adopted was the same in principle. One, two, or more wells were made outside the excavations, and if possible a natural bed of gravel reached. If not, then gravel was put in, and the water pumped through it. By such means it was often possible to pene-

trate sand which it would be dangerous to draw off, especially when that sand was underlying adjoining buildings.

The Crossness Pumping Station in Plumstead Marshes, being close to the Thames, and the foundations 36 feet or 37 feet below Trinity high water, required two large and deep wells, two 40-HP. engines and pumps throwing 5,000 gallons each per minute; besides, at different times, and on different parts of the work, six other sumps, making an aggregate of eight wells, as many engines and pumps, and 150 HP., capable of discharging 17,000 gallons per minute, though not all at work simultaneously. It was only by such means that it was possible to get in the foundations safely, and keep the finer sand from blowing up.

Mr. Homersham said he understood that the trouble experienced at Hull from blow-wells was caused by the silt, or fine sand, brought up with the water that issued from bore-holes artificially sunk through the London clay. In the case referred to by Mr. Grant they were actually working in the sand itself, below the London clay, while at Hull there was a bed of 80 feet or 90 feet of clay above the sand or silt, lying between the clay and the chalk. The water that came up through the bore-holes was derived from the chalk formation that cropped up to the surface from Hull, in a westerly direction, for a breadth of 10 miles, gradually rising into hills that at places attained to heights varying from 400 to 800 feet above the sea, and extended in a northerly direction for upwards of 30 miles in length. The great mass of the rain falling on the chalk hills was absorbed, and fed the sand lying between the London clay that at lower levels was superimposed upon the chalk, so that directly a bore-hole was put in through the clay the water overflowed, bringing the silt with it. At Bridlington, to the north of Hull, it was no uncommon thing to put a bore-hole through the London clay, even in the sea itself, then to drive a pipe down into the chalk, and so allow the fresh water to overflow above the surface of the sea. Ships' boats were thus supplied with water. At Grimsby, to the south of Hull, overflowing wells were made in just the same way. When the excavation to form the docks was in progress, if all the holes had been carefully filled up below 33 feet from the surface, the greatest depth excavated, there would have been no overflowing sand nor any blow-wells. This might easily have been done by putting in a pipe 4 or 5 inches in diameter to near the bottom of the hole, and running down liquid concrete. It was essential that the water should not be allowed to rise through the bore-holes while concrete was run in, and this being attended to, the hole

could be filled up with cement concrete and made perfectly sound. He had done this in some cases when the holes were 300 feet or 400 feet deep, and from 10 inches to 24 inches in diameter. The pipe used through which the concrete was lowered was of wrought iron, and the concrete composed of 2 parts of coarse sand mixed with 1 part of Portland cement. If it was inclined to set too quickly a little treacle should be dissolved in the water used to make the concrete in. The tube was gradually drawn up as the hole was filled. Where the holes were small a screw might be run down, and the sand thus stopped from coming up. The difficulty in Hull arose from allowing the sand to come up at all, and not stopping the holes at once. In many such holes the water rose higher at high tide than at low tide. When the overflow actually showed itself, a simple means of stopping the rising water and sand was to lower a cast-iron tube through any gravel or silt lying on the surface of the clay, sufficiently deep into the clay to make a water-tight joint, the top rising to just above where the water would reach at high tide. A tube might then be inserted down to the bottom of the hole, and the liquid concrete run through it until the hole was perfectly filled. He drew attention to this because it had been suggested that the overflowing water from the holes came from the sea itself. Now, it was not sea water, but subterranean fresh water from the chalk hills that came up the bore-holes charged with silt and sand. The holes were originally sunk for the purpose of getting a supply of fresh water, and when the clay was passed through the water overflowed. Every one of the holes should have been at once stopped up in the way he had described as soon as ever overflowing water appeared. The blow-wells were caused by holes sunk through a thickness of 80 feet to 90 feet of clay, and were not natural holes.

Mr. Cowper said in one case he had to build a chimney 6 feet in diameter, 100 feet high, on a quicksand; for after passing through about 4 feet of good gravel, he came to a bed of yellow quicksand, and it was utterly hopeless to try to get to the bottom of it. He cut out the gravel in notches all round very carefully, and filled the excavation with Portland-cement concrete, and the chimney had stood very well to the present day.

Mr. Bateman, Vice-President, said some years ago having to overcome a powerful spring at the bottom of a shaft, he found no way of doing it except by nearly filling bags with shot and sinking them to the bottom of the shaft. The bags, not being quite filled, took their shape one against the other, and effectually overcame the difficulty.

Mr. Du Plat Taylor thought the design of the warehouses and of the whole machinery of docks should be left to the engineers who were entrusted with the construction of the docks themselves. That the concern should pay was a material point; but in considering this he thought the fixed cranes so commonly used were not adapted to the present requirements of trade. Formerly the ship came alongside the quay and remained undischarged a fortnight or three weeks without any complaint being made: but now when a steamer arrived it was expected that she should be discharged within forty-eight hours. In his opinion, therefore, the fixed hydraulic cranes should be abandoned, and movable hydraulic cranes, movable to such an extent as to plumb the hatchways, should be more generally adopted. Another matter to which he wished to draw attention was that of the warehouses. In the South Dock of the West India Docks, London, which he considered one of the finest in the world, a most splendid warehouse had been constructed by Sir John Hawkshaw, but he thought one mistake had been made there. He had visited all the ports of England, and had found that any storage of goods higher than a man could reach did not pay. No floor of a warehouse should, therefore, be higher than 9 feet. In the South Dock the floors were 16 feet, and everything beyond 9 feet was waste space. The high warehouses at that dock might easily have had six floors instead of five, and the revenue derived from them might thereby have been considerably increased. The only dock which answered the requirements of London was the Victoria Dock, where there were jetties and appliances for discharging the largest ship in twenty-four hours. The goods were taken across the jetty and put into barges. In the South Dock, where ships were also discharged with the greatest despatch, there were no jetties, and the goods remained there for some time, it not being possible to get barges alongside the quay for the removal of the goods. He hoped no more docks would be constructed in London, there being enough, but if there were, the only form of dock that was really advantageous was where ships were brought alongside a jetty, so that the cargo, after landing, could immediately be taken away in the barges to the warehouses. Mr. Manning, the engineer of the East and West India Dock Company, who was present, was in favour of steam cranes for many purposes, in preference to hydraulic cranes, and in this he concurred.

Mr. Pearsall remarked that formerly baths were constructed on the spot where the difficulties had been met with in excavating for the dock at Hull. Borings were made, and at a comparatively

small depth water of a highly medicinal character came up. It was ferruginous, and contained carbonate of magnesia, which, with other salts, precipitated crystals. Further borings were made until salt water was reached. At about 1¼ or 1½ mile above the town the bottom of the Hull river was at a higher level than the land on each side, and was kept up by the banks all the way to Driffield. There was thus a great source of pressure.

Sir JOHN HAWKSHAW said Mr. Homersham must have forgotten that at the time the boils occurred, the clay was overlaid by a bed of sand, and it was through the sand that the water made its way. It was not then known that it was coming from bore-holes, and for a long time it was assumed that the source of the water was the river Humber. The holes were not discovered until long subsequently; and therefore plugging them with cement was out of the question.

Mr. J. CLARKE HAWKSHAW said the borings which proved so troublesome were made before the works were begun, and nothing was known about them, as they were not executed for the purposes of the work. Only one boring was made at the east end of the lock for the purpose of the works before they were begun, and that was misleading as to the nature of the strata there. He thought, therefore, there was just as much danger in having too few borings, as too many. One great difficulty in dealing with the sand was the compact nature of the clay. When the water carried away sand from under the clay, the clay, being solid and compact, did not settle down, and a cavity was left beneath it. This greatly increased the difficulty, because a settlement was not found out until it was almost too late. The supply of water was practically unlimited, and no number of sumps and pumps, as recommended by Mr. Grant, would have sufficed to drain it off. Owing to the width and size of the lock a great number of small craft, especially fishing-boats, were often taken in at one tide. While the works were going on, he was much impressed with the necessity of using despatch in getting in foundations where there was any chance of blow-holes, as in many cases a blow was avoided by prompt action. Where there was a spring, clay was piled up to stop it; the clay was then excavated, and, by using all despatch, the foundation could be got in before the boil burst out again. The cranes were those ordinarily used in docks. The swing bridge was worked by hydraulic power.

Mr. JAS. A. M'CONNOCHIE said that portable hydraulic cranes were first introduced at the Bute Docks, Cardiff, about five years ago, when, on the suggestion of the Engineer of the Docks, Sir

William Armstrong and Co. designed and supplied these cranes, to meet the varying distances between the hatchways of vessels. The construction was that of the ordinary pillar hydraulic crane, mounted on a travelling carriage. Hydrants were placed on the hydraulic main, about 20 feet apart, and the water pressure was supplied from them to the cranes through wrought-iron pipes with union joints. Four of these cranes were in use at the Bute Docks, three lifting 46 cwt. each, and one 27 cwt.; and in the case of those used for loading and discharging the Atlantic steamers, the cranes travelled on an elevated staging over the railways on the quay-level, which were thus uninterfered with. Portable hydraulic cranes had been adopted at Barrow, Holyhead, Liverpool, and in India.

Mr. Cowper observed, that on the Seine, at Rouen, he had watched the loading and unloading of steamers, by fixed steam cranes on the quay, and floating steam cranes on barges or dummies. The steamer was no sooner alongside than the floating cranes came outside her, and unloaded into barges lying outside them such materials as had to go into the barges, whilst materials for the quay were landed there. Thus five steam cranes were at work on the vessel besides her own steam winches, and the work was done far more quickly than alongside any single wharf.

Mr. Harrison, President, said he was afraid he was one of those who had put down several of the bore-holes on the site of the Hull docks; and the result was that in the dock he designed the work was removed out of the way of the difficulties that had troubled Sir John Hawkshaw, who successfully completed the dock. Mr. Homersham assumed that the water from the bed of sand would rise to a considerable height; but his experience at Hull, within 3 miles of the town, was that it did not do so. He had sunk wells from which water was being continually pumped, and the water did not rise above the level of high water. The wells passed through the same beds of clay that Sir John Hawkshaw had found to the bed of sand. Mr. Homersham's plan for stopping a leak from a bore-hole would be exceedingly simple, if all the circumstances were such as had been assumed. He had done exactly the same thing, where he had found the masonry deposited as a foundation rise 3 inches in a conical shape. On putting a bore-hole through the clay the water rose, and was conducted away by a pipe, and the difficulty was overcome. In that case the clay was on the surface; while at Hull the water poured up in some places in spouts almost as thick as a man's body, and putting a plug down to stop it was out of the question.

Whether steam cranes were preferable to hydraulic cranes must entirely depend upon the circumstances under which they were used. He had employed hydraulic power as much as any one, and also steam power to a very large extent in connection with docks, and he considered both kinds of cranes were useful, one being more suitable in one case, and the other in another. If a rule were to be laid down, however, his experience was that the hydraulic crane was superior to the steam crane.

It was specially resolved to adjourn for a fortnight, in order to avoid holding a meeting on the evening of Easter Tuesday, March 30.

SECT. II.—OTHER SELECTED PAPERS.

No. 1,400.—"Experiments on the Portland Cement used in the Portsmouth Dockyard Extension Works." By CHARLES COLSON, Assoc. Inst. C.E.

ALTHOUGH the manufacture of Portland cement has been greatly improved of late years, and further knowledge has been gained as to its properties, there is still much to be learnt; and it is mainly from the records of experiments and observations made during the execution of large works, with cement supplied from different manufacturers, that data can be obtained on which to found a true estimate of its value. While not in the power of every one to enter into an elaborate series of experiments, yet it is possible, and, in fact, is absolutely necessary, to test the material continually, in order that the strength may be kept up to the required standard.

With a view, therefore, of adding to the existing knowledge on this subject, the Author has tabulated the details of the tests made by him during the execution of the works of the Portsmouth Dockyard Extension, the results being given in Appendix B, page 143. The specification provided that the cement should be of the best quality, ground extremely fine, and should weigh not less than 112 lbs. to the imperial striked bushel, as poured from a sack into the measure. The cement was to bear a tensile strain of 450 lbs. on $2\frac{1}{4}$ square inches without breaking at the end of seven days' immersion in water. It was also provided that samples for testing should be taken from every tenth bag, if required. It was not, however, deemed necessary to proceed to the extreme limits stipulated for in the specification; but, on the arrival of each cargo, sufficient cement was taken to make seven briquettes, four of which were placed in water as soon as they were sufficiently set to admit of their being removed from the moulds, the remainder being kept dry. At the expiration of seven days three of the wet briquettes and the three dry ones were tested in the machine, the remaining wet one being reserved.

The moulds for casting the briquettes were constructed with wrought-iron side frames, and brass divisions secured in position

by a bolt through each end. In use the frames were placed upon cast-iron bed-plates planed to a true face. When it was required to take the briquettes from the moulds, the end bolts were released and the side frames removed. The number of moulds in each frame was seven, that being the number appertaining to each cargo of cement. The correctness of the moulds is of the highest importance, because, unless they are perfectly true at the shoulders, so as to insure a uniform bearing in the clamps of the testing machine, a fair test cannot be obtained.

Every care was taken in gauging the cement for the test bricks, and, as far as possible, the same proportions—by measure—of cement and water were used. It was, however, necessary to vary these proportions slightly at times, the age and temperature of the cement causing a difference in the requisite quantity of water; for instance, new fresh-ground cement absorbed more water; but, on the whole, the proportion of water to cement was 1 to 3, which was sufficient to mix it to a workable consistency. The testing apparatus, capable of being used up to 20 cwt., was one of Pooley's steelyards, fixed in a timber frame, the clamp for holding the lower part of the briquette being fixed to the sill of the frame.

With regard to the method for weighing the cement, it was found, after repeated trials, that a uniform result could not be attained by following the course described in the specification, viz., simply pouring the cement out of the bag, as it was impossible to maintain a uniform rate of delivery. If the cement was allowed to fall from the bag too quickly, the measure became filled with a mass of cement of the same density as when in the bag, in which it had become consolidated by being shaken and moved about. To obviate this difficulty, and to equalise the density in the measure as much as possible, an ordinary hopper stool was adopted. This was about 2 feet 6 inches high, with a shoot fixed on the top; the lower end, or neck, was contracted to 7 inches by 2 inches, to prevent the cement from falling into the measure in heavy masses, in case it should escape from the bag too quickly. The measure, being heaped up, was allowed to stand for a few minutes, in order that the cement might settle. When no further subsidence was observed the surplus was struck off the top and the rest weighed. By this method it was found, by repeated trials with the same cement, that a uniform density was obtained.

Another point, of the greatest importance, is the degree of fineness to be observed in grinding the cement. In specifications generally it is simply provided that the cement is to

be "ground extremely fine"—a somewhat vague term, and one which leaves it very much to the judgment of the manufacturer as to what the term extreme fineness may be regarded to mean when applied to cement. A reasonable interpretation would be, that it implies an impalpable powder, because the coarse or unground particles have no value whatever as a cementing ingredient. For example, if a quantity be screened and the residue be mixed in the ordinary manner, it will be found that the residue has no more cohesive power than ordinary sand; hence it may be inferred that, when used in mortar or concrete, the effective quantity of cement is affected by the proportion of coarse or unground particles in the mass.

Table I. shows the average proportion, by weight, of coarse or unground cement contained in that supplied to the works during a period of about four years. The method of ascertaining the proportions was to take 1 bushel from each cargo, and to screen it through wire gauze having 1,152 meshes to the square inch. The coarse was in each case carefully weighed under the same conditions as the bulk of the cement.

It was also found that the average weight per bushel after screening was 106 lbs., against 115 lbs. before screening, as delivered on the works. These results show that the cement, as received from the manufacturer, is affected to the extent of between $\frac{1}{4}$ and $\frac{1}{5}$ of the gross weight, or about 21½ per cent., by coarse grinding. To specify a given weight per bushel without fixing the degree of fineness to be observed is an incentive to bad grinding; further, it is not only embarrassing to persons who have the responsibility of examining and testing the cement, but is calculated seriously to mislead those who are not fully versed in its nature and properties, inasmuch as when a sample of light weight comes under notice, it is supposed that it must necessarily be an inferior cement, when in reality it may be of superior quality.

Table II. gives the breaking strains of a few samples of light cement. Although these samples were not all tested for fineness, it may be reasonably inferred—from the fact that the general result of tests extending over a considerable period, and including thousands of bushels, gave 106 lbs. per bushel after screening to the extent described—that, besides being of a superior quality, all were ground to a great degree of fineness.

Neither, on the other hand, can it be taken for granted that the quality of cement is superior on account of greater weight. Indeed where a high degree of tensile strength is specified, more care should be exercised, because, in order to obtain the required

strength, a greater proportion of lime, or rather chalk, is used in the manufacture; therefore, unless burnt to a high degree, the danger of flying is augmented, whilst the weight of such underburnt cement can be kept up by coarse grinding.

These remarks have reference chiefly to the fallacy of judging of the quality of cement by the weight alone, rather than to the effect of fine grinding upon the tensile strength.

Again, care is required in testing cement for tensile strength, not to condemn a possibly good sample unless it has reached the specified standard of strength. It frequently happens that trial is made of cement fresh from the kilns, or which has been put into casks or bags immediately after grinding; and although complying with the weight condition, it has been found to fail, when tested for tensile strength. Such a result is produced in many instances by heat imparted during the process of grinding, and retained by the cement being inclosed in casks or bags. The confined heat causes the cement, when gauged for testing, to dry before the action of setting can effectually take place, and thus is frequently the cause of the apparently inferior quality of the cement. In such a case it is necessary to spread the cement out on a floor for a few days, turning it over occasionally, in order that it may be thoroughly cooled; after such treatment, provided the quality in other respects is satisfactory, it will generally come up to the specified standard, if not exceed it. The same appearance of rapid setting may, however, be brought about by an excess of chalk, producing free lime in the cement, which would give off considerable heat on being gauged, causing the cement to "go off" in the manner referred to; but in the event of free lime being present, the briquette would probably expand and crack on being placed in water. Table III. shows the results of such treatment.

Table IV. gives the average strength of Portland cement supplied by each manufacturer during a period of about five years; including the results of both wet and dry tests, each being at the end of seven days. For the wet test the average breaking strain was 781·2 lbs. on $2\frac{1}{4}$ inches area, or 347·2 lbs. per square inch; for the dry test the breaking strain was 747·3 lbs. on $2\frac{1}{4}$ inches area, or 332·1 lbs. per square inch. The result was therefore in favour of the wet test, to the extent of 4·5 per cent.; although in two instances in detail the reverse was found to be the case, the average dry test showing a greater tensile strain than the wet. These results show that the standard of strength originally specified, viz., 450 lbs. on $2\frac{1}{4}$ square inches at seven days in water, has been exceeded by 331·2 lbs., or 73·6 per cent.; whilst in the

cement supplied by Hilton and Co., the increase of strength above the specified standard has been 454·6 lbs., or 101 per cent.

Table V. shows the breaking strain of Portland cement at thirty days, compared with the breaking strain at seven days old, both samples being kept in water.

Undoubtedly the fairest way would be to test cement at thirty days, inasmuch as the harder burnt varieties, requiring a longer time to set, are placed at a considerable disadvantage compared with the quicker setting cements when tested at the end of seven days. They do not show such good results as would be the case if a longer time were allowed to intervene. It will be seen by the table that the cement, which was strongest at seven days, gave at thirty days a less percentage of increase of strength than the cement which gave the least result at seven days. In the first case the percentage of increase was 29·3, and in the second case 39·6 on the breaking strain at seven days. In order to obtain these results, the same number of tests were made at the expiration of seven days and thirty days respectively upon briquettes from the same samples.

Not only does the demand for high tensile strength at seven days practically exclude from competition all the harder burnt, slower setting, though ultimately stronger cements, but it has the effect of forcing the quicker setting cements to such a degree, that the risk of the presence of free lime, and consequently the danger of expansion, is augmented. Much, however, can be said on the other hand, in support of immediate strength, and in some cases it would of course be necessary. As, however, Portland cement is now frequently used for other than submarine works—amongst which may be mentioned, buildings with comparatively thin walls, to which the risk of expansion would be doubly dangerous; or works of a massive character, where, although superior ultimate strength would be the *sine quâ non*, great immediate strength would not be required—it becomes necessary to inquire, what, under the varying circumstances of engineering practice, should be the conditions of manufacture or of testing to insure a cement best suited for each particular work? In the Author's judgment it would conduce greatly to the ultimate strength and safety of the work to abandon the seven-day test, and to adopt an increased tensile strength at twenty-eight or thirty days. By making the time between mixing and testing thirty days, in place of seven days as at present, some inconvenience might perhaps at first be experienced; increased storage room would also be necessary, in order that a stock might be kept in hand sufficiently large to

meet any contingency, but there appears to be no valid reason why thirty days should not be the recognised time.

Tables VI., VII., VIII., IX. and X. show the increase in tensile strength from seven days to twelve months, a sample having been taken from each consignment delivered on the works. In these tables it will be again observed that the slowest setting, or the cement showing the least tensile strength at seven days, exceeded in strength, at the expiration of twelve months, the quicker setting cements, or those showing the best results at seven days. The least tensile strain, viz., 589 lbs. on $2\frac{1}{4}$ square inches, increased to 1,500 lbs. at twelve months, giving a percentage of increase of 155; whilst the highest result at seven days, viz., 1,000 lbs., at the end of twelve months, increased to 1,241 lbs., giving a percentage of 24 only. These tables do not show the average strength of Portland cement of each separate manufacture at twelve months, but are introduced for the purpose of proving that it by no means follows that cements, giving the best results at seven days, will always increase in strength in the same ratio as the slower setting cements.

Tables XI. and XII. show, comparatively, the average tensile strength of each manufacturer's cement at twelve months and at two years. In these results the same thing is to be observed, viz., that the slower setting cements attained a greater ultimate tensile strength than the quicker setting cements. These tests were made from separate samples, taken from the cargoes as they arrived at the works, and extend over a considerable period; they therefore represent the tensile strength of the cement used on these works, at the ages named.

Tables XIII. to XVI. indicate in detail the effect of weight on the tensile strength of Portland cement. They give the average breaking strains on $2\frac{1}{4}$ square inches for each separate manufacture; and show that the general rule, that the strength of Portland cement increases with the weight, will not, under all circumstances, hold good; that the regular increase of weight is no true indication of a proportionate increase of tensile strength. Such an assumption is perhaps rather calculated to mislead than otherwise; as an illustration it may be mentioned that, during the execution of these works, it was found necessary to condemn two cargoes weighing 115 lbs. per bushel, in consequence of failure of tensile strength after repeated trials. The cause of failure in this case was undoubtedly an excess of clay. In another instance, however, the weight, 107 lbs. per bushel, may perhaps have had some value as indicative of inferior quality. About 120 tons were

rejected in consequence of failure when put into water—the blocks cracking and flying in all directions. The weight per bushel, although low, cannot be looked upon as excessively so, or as giving a true indication of the inferior quality of the cement.

An examination of these tables will show that, as delivered on the works, so far from the cements of the greatest weights giving the highest tensile strength, the reverse has been the case in many instances, the cements of the least weight per bushel showing the highest resistance to tensile strain. Only in one instance does there appear a tendency to an increase of strength with the weight, viz., the cement manufactured by the Wouldham Company; but even in this case, if the table is examined in detail, it will be observed that, although the averages show this increase, it is not an uniform one from 114 lbs. to 124 lbs.; and it will also be noticed that the average increase is not caused so much by an uniform increase of strength under those particular weights, as by the presence of a few tests giving a greatly superior resistance to tensile strain.

The cause of this variation in the weight may perhaps be attributed more justly to the quality of the grinding than to the quality of the cement. It has already been shown, Table I., that the degree of fineness varies considerably in the cement made by the different manufacturers; it was also found that the cargoes delivered from each manufacturer varied to a considerable extent in this respect; therefore, without some fixed degree of fineness, to be recognised and observed by all manufacturers and engineers, no reliable data can be obtained on which to found an opinion under this head. That when reduced to a uniform degree of fineness, the heavier, and consequently the harder burnt cements, would give the best results there is perhaps little doubt; but, until some such standard is established, it would be better that less stress should be laid upon the weight as an element of quality. It is not intended to suggest that the question of weight, under present circumstances, is to be ignored as a matter of no importance. On the contrary, it is a point to be carefully attended to, and the results noted, inasmuch as it is only by the careful examination of a matter in all its bearings that a sound opinion can be formed as to when and to what extent improvements can be made. In this instance, it is more particularly intended to draw attention to the necessity of an universally acknowledged standard of fineness.

Table XVII. shows the breaking tensile strain of Portland cement and sand, in the proportion of 1 of cement to 2 of sand, from six months to twelve months. The mortar for these

tests was taken as mixed for and used in the work. Table XVIII. shows the breaking tensile strain of cement and sand in different proportions, and also of neat cement. These were made from a sample manufactured by Francis and Co. The general average breaking strain of mortar as used on the work, at one month old, as shown by one hundred and eighteen tests, was 246 lbs. on 2¼ square inches. The sand was clean coarse grit, obtained chiefly from Langston Harbour or the vicinity. An average of three tests of the same description of mortar, at the end of three years, gave 1,173 lbs. on 2¼ square inches. With regard to the mortar taken as mixed for the work, it should be observed that more water is used than would be the case in ordinary testing. This would, of course, affect the results.

It was suggested, during a discussion on the subject of Portland cement,[1] that probably the better way would be to test all cement with an admixture of sand in the proportion destined for the work, generally 2 of sand to 1 of cement. There is, no doubt, considerable reason in such a suggestion, inasmuch as a record would be preserved of the tensile strength of the cementing material as used; whereas at present the tensile strength of the neat cement is, as a rule, the only point attended to. This must, of course, always hold the first place in the practice of cement testing, as a means of insuring a high standard of quality; but it would add considerably to the interest and value of the records, if data were collected from which the actual strength of the cement mortar as used in the work could be estimated. Such knowledge would enable engineers to apportion the sand to cement to suit the varying nature of the materials. If the cementing ingredient has a cohesive strength equal to that of the building material, it would appear to be all that is required to insure the stability of the work. Of course regard must be had to the varying adhesive qualities of different materials, the rough and absorbent having greater adhesive power than the smooth and dense. It should also be borne in mind that such information should detail the nature and qualities of the sand used, because on this would depend very much the results of such tests, and the value of them as a guide in future practice.

Table XIX. has reference to the tensile strength of Portland cement when mixed with and kept in salt water. It was long considered, and is so now by some, that salt water had a deteriorating effect upon Portland cement; but it has never been explained by what chemical action, between the salts in the sea-water

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxii., p. 317.

and this particular kind of artificial cement, the supposed deterioration is brought about. The conjecture may probably be founded on the fact (as recorded in Burnell's valuable little book on limes and cements), that with the earlier artificially made hydraulic limes and cements some failures appear to have taken place, which led Vicat and others to think that these failures were due to the salts of magnesia contained in the sea-water with which the works were in contact. The supposition is that the magnesia acted upon the imperfectly carbonated parts of the cement, causing thereby important chemical changes, accompanied by a mode of crystallization different from that of ordinary carbonate of lime, which, doubtlessly, led to disintegration and failure.[1] It should, however, be observed that the limes and cements here referred to were made with puzzolano artificially prepared from clay, and it was supposed to have been the action of the salts in the sea-water upon this ingredient which caused the failure of the whole. But inasmuch as Portland cement, as at present manufactured, is of a somewhat different character to those limes and cements on which the theory of the injurious nature of sea-water was founded, the clay being intimately incorporated with the carbonate of lime before calcination, as suggested by the same writer, the above reasoning is hardly applicable. It is, however, an interesting as well as an important point for consideration, as to what are the real or supposed objections to sea-water for mixing the cement and wetting the building materials to be used in the work. As far as the Author is aware, no reported failure has ever been attributable to this cause; in fact, all experience is to the contrary. The results of works executed during the last few years with Portland cement, in connection with Marine Engineering, have been of such a satisfactory nature as to prove the fallacy of these opinions. It has also been shown by careful tests that Portland cement, when mixed with salt water, gives better results than when mixed with fresh water.

For mortar or concrete destined for the construction of "buildings," it is undoubtedly injurious to employ other than fresh water, on account of the deliquescence of the salts contained in the sea-water, particularly during humid weather; but in coast or harbour works there appears to be no valid objection to its use.

The chemical action of water upon cement, and the changes during the process of what is commonly known as setting, have never been fully explained. In this direction there is great scope

[1] Burnell "On Limes and Cements."

for research, and it would be a boon to the profession generally if those who have the requisite chemical knowledge would take up this part of the subject. The following extracts from an article on Portland cement in the "Engineer" of July 29, 1870, may be of interest, as bearing upon this part of the subject:—

"The chemistry of the setting of Portland cement is by no means so well understood as it ought to be. There is no doubt, however, that, like the hydraulic limes and natural cements, it is, chemically speaking, a double silicate of lime and alumina; silicic acid is generated by the hydration of the cement, and forms insoluble salts with the lime and alumina bases."

With regard to the action of sea-water upon Portland cement, it is also remarked, that "it is a curious fact that Portland cement hardens more rapidly when salt water is used for the hydration than when fresh water is employed. May not this arise from the following causes? According to Schewertzer, 1,000 grains of sea-water in the English Channel contain 27·06 grains of chloride of sodium; soluble silica has a known preference for alkaline bases, and it is not improbable, when the cement is hydrated with sea-water, that the chloride of sodium is decomposed, the silicic acid of the cement combining with the sodium and oxygen of the water, and forming thereby a silicate of soda, or a species of crude glass. To this cause we attribute the more rapid hardening when salt water is present."

As to the conditions of manufacture affecting or controlling the tensile strength and rate of setting of Portland cement, the Author is enabled (through the kindness of gentlemen who, from long experience in its manufacture, are well able to form an opinion) to add the following remarks, bearing in some measure upon this part of the subject.

These conditions of manufacture may be divided under four heads, viz.:—

1. The proportions of chalk and clay.
2. The degree of calcination.
3. The degree of fineness.
4. The age of the cement.

The last is not, perhaps, strictly a condition of manufacture; but, as it has been found to exert considerable influence upon the rate of setting, it has been deemed advisable to refer to it.

With reference to the first condition, it is impossible to establish any fixed proportion for the chalk and clay, inasmuch as it must depend entirely upon the quality of each considered

separately. This would, of course, vary considerably in different districts, according to the geological position of the strata from which the raw material was obtained. For instance, the grey chalk, containing a large percentage of clay, would require less of the latter to be added to it; whilst the white, or upper chalk, being almost pure lime, would require more clay. Again, the clay, if obtained from the beds of rivers flowing through a chalk district, may contain lime, which would necessitate a reduction in the quantity of chalk to be added in the manufacture of the cement. The constituents of these ingredients can only be ascertained by analysis, careful tests, and observations; the knowledge thus obtained forming the basis of the proportions of chalk and clay to be adopted in the manufacture of Portland cement in each particular locality.

But, whilst fixed proportions cannot be given, it may be stated in general terms, that where a high tensile strength is demanded, a greater proportion of chalk must be employed. This, if properly burnt, will produce a slow-setting, but eventually a very strong cement. There are, however, reasons why, in general practice, a high proportion of chalk should be avoided; the principal one being the great danger of an excess of that ingredient producing free lime, which would cause the cement to swell and crack, and eventually to fall to pieces. Again, cement with a high proportion of chalk (*i.e.*, in excess) has not the same hydraulic properties as cement with a less percentage of chalk, a full proportion of clay being necessary to insure these. On the other hand, an excess of clay will give a quick-setting, but, at the same time, a very weak cement, with a muddy appearance and yellow colour. The simple fact, as regards the proportions, appears to be that a certain quantity of clay is required to neutralise a certain quantity of chalk: what these proportions should be must be based entirely upon the constituents of the raw materials, which would depend (as before remarked) upon the geological position, and possibly upon local influences.

As regards the proportions affecting the rate of setting, it appears that a high proportion of chalk (not in excess) will cause this action in the cement to be slow, whilst an excess of chalk, producing free lime, will evolve considerable heat on being gauged, causing the cement, apparently, to set much more quickly: when in this condition there is the greatest danger of its flying. The addition of clay increases the rate of setting, and when present in excess this will be very speedy. After the first, however, it will harden very gradually, and that only to a limited degree.

With reference to the degree of calcination, the quality of the cement depends, to a great extent, upon the perfection to which the operation of burning is carried. To insure this, care is required in putting into the kiln the proper proportions of cement and coke, and also in regulating the heat, in order that the whole mass may be evenly burnt. If the cement be under-burnt, it will have little or no strength, and within a short time will become disintegrated and fall to pieces. Cement, when properly burnt, should have the appearance of a hard clinker just on the verge of vitrifaction: in proportion to the high degree of burning so is the strength of the cement improved. It is, however, possible to burn to excess, so that the properties of the cement are injured. The degree of calcination affects also the rate of setting to a considerable extent, inasmuch as the harder the cement is burnt, the longer time it requires to set.

There is considerable diversity of opinion as to the extent to which mechanical pulverisation should be carried, considered from a commercial point of view, and as affecting the strength of the cement. The following quotation, from remarks upon the subject by a well-known firm of cement-manufacturers, will throw some light upon the opinions obtaining on this point:—"Unquestionably, the finer the cement is ground, the more perfect it is; but to reduce the whole to an impalpable powder is never attempted nor expected, it being, commercially speaking, impossible to do so at the price cement commands. Nor do we think it would answer the purpose either of consumers or of manufacturers to attempt this, the extra cost of reducing the particles of unground cement, which can always be sifted from the best Portland cement, being more in comparison than it is injured by their presence in a reasonable proportion. For this reason it is sometimes specified what percentage of unground particles will be admissible. We would remark here that, owing to the difficulty in practice of reducing the whole of very hard cement to an impalpable powder, we consider it unwise to specify a very heavy weight per bushel, which is often obtained at a sacrifice of tensile strength. The desideratum being a high tensile strain, this is sometimes more readily insured by a cement weighing comparatively less per bushel than by a very heavy one, the latter being produced not only at the risk of being over-burnt, but in practice is sure to contain a larger proportion of unground particles than one more evenly but not so hardly burnt."

With regard to the effect of fineness upon the tensile strength of Portland cement, there is little doubt that, when ground ex-

tremely fine, the power of resistance to tensile strain in the neat cement is reduced, as will be seen by the result of experiments at the expiration of one month (Table XX.). These tests were made from samples taken at intervals from four cargoes delivered from each manufacturer. One portion was screened through wire-gauze containing 1,152 meshes to the square inch and afterwards gauged in the ordinary way; a second portion was mixed in the state as received; twelve tests being made in each case. From these results it will be observed that the screened samples do not show so great a resistance to tensile strain as the unscreened.

Whether this reduction of tensile strength is to be regarded in the light of a permanent weakening of the cement, is a question of considerable interest. Further experiments on this point tend to strengthen the belief that such is the fact; in one case only does the fine cement take the first place, and then but to a limited extent. Whilst, however, these experiments are conclusive as far as they go, it must be admitted that they are not of a sufficiently extended character to admit of a definite opinion being formed.

When, however, the finer cements are gauged with sand, the advantage of a greater degree of fineness becomes apparent. The proportions of sand in these experiments were such as would be tried in ordinary practice, viz., 1 of sand to 1 of cement, and 2 of sand to 1 of cement (Tables XXI. to XXVI.). The fine cements, with one exception, gave the best results—strong evidence in support of the opinion already expressed, that greater attention should be given by engineers and manufacturers to this important point.

It is, perhaps, difficult to explain the fact of the coarser cements being the most valuable. Possibly the coarse or unground particles, although possessing no setting property of themselves, may have great adhesive power and affinity for the perfectly-ground cement, and thus form, as it were, a key or bond uniting the whole mass. With regard to the increased tensile strength of the fine, as compared with the coarse cement when mixed with sand, it may be accounted for by the latter containing a large proportion of unground particles, which, although acting as a bond when gauged neat, would, on the addition of sand, be distributed through the mass, thereby loosing, or at any rate reducing the influence they would have as a key; the actually effective cement being the difference between the original quantity and the proportion of coarse or unground it contains. This proportion has been ordinarily about 21 per cent. The cement

would, therefore, be reduced in about this proportion, whilst the sand would be augmented; thus, in the case of 1 to 1, the actual proportions would be ·79 of cement to 1·21 of sand. In the case of the fine cement, the proportions would be as stated, the mass therefore containing a greater quantity of effective cement, which would go far to account for the superior tensile strength ascertained from these experiments.

It has already been observed that the quantity of water used in gauging the cement has great influence upon the tensile strength. If an undue amount be employed, it is reduced to a considerable extent; on the other hand, if the quantity be as small as possible consistent with proper manipulation, the result will be much higher. From numerous experiments and observations it was found that, as a general rule, a proportion of 1 of water to 3 of cement by measure, or 1 to 3½ by weight, was the best, both as regards convenience of mixing and results. With a much less quantity, the gauging would be so stiff as to render the manipulation most difficult, the risk of air-holes, the reduction of which to a minimum is a point to be particularly attended to, would be augmented; the angles of the mould would be imperfectly filled, and generally a very imperfect briquette formed; consequently the results of such tests would be unsatisfactory and unreliable. A much greater quantity of water would have the effect of reducing the tensile strength, thus rendering the results of tests equally unsatisfactory and unreliable. Of course, in general practice, it will be found that a slight variation in the above-mentioned proportions will be necessary, depending upon the age and degree of fineness of the cement, but only to a limited extent.

Table XXVII. shows the tensile strain, at seven days, three months and six months, of three samples from the same cargo, but mixed with different proportions of water; the average of seven tests being given in each case. The results at six months are not so high as might be expected, the two last in fact showing somewhat less strains than those recorded at three months. This may perhaps be accounted for by the fact that these tests were made during severe frost.

It has been suggested that, although the cement mixed with an excess of water gives an inferior result at first, it would in course of time recover itself and ultimately show a tensile strength equal to the cement mixed with a minimum of water: the results shown in Table XXVII. controvert this opinion. If it were so, the difference in tensile strength at seven days, between the samples mixed with different proportions, would at the end of longer intervals be

lessened; instead, however, of such being the case, it is on the contrary greater; a circumstance which would rather lead to the conclusion, that not only does the minimum of water give the best results in the first instance, but that cement so mixed increases in tensile strength in a higher ratio than when a greater quantity of water is used.

The age of Portland cement, although strictly speaking not a condition of manufacture, is nevertheless an important element in its economical and safe use; it not only improves generally by keeping, but the older the cement (especially now that such high tensile strains are called for) the less danger will there be of its flying, inasmuch as free lime, arising from an excess of chalk, would be acted upon by the atmosphere, causing it to slake, and thereby reducing the danger of expansion to a minimum. The age has also been found to exert considerable influence upon the rate of setting, causing it to require a much longer time to set than new cement. Generally, the older and slower-setting the cement, the harder it will eventually become; hence—as remarked in a previous part of this Paper—in comparing different cements, seven days' interval between mixing and testing does not always give just results.

The most reasonable inference to be drawn from the foregoing remarks appears to be, that the strength of Portland cement depends on the suitable proportions of chalk and clay, which can only be determined by analysis and experiment; on the absence of sand and foreign matter either in the clay or chalk; on the proper amalgamation of the raw materials, and upon the sufficient burning and grinding: in fact, its quality depends not on one particular condition being strictly observed, but upon the perfection with which each separate branch of the manufacture is conducted.

In concluding these remarks, the Author would again draw attention to the necessity of uniformity of procedure with regard to grinding or screening, and also in testing Portland cement; any observations bringing to light new facts would of course be of great value: but this would be considerably increased if more uniformity were observed than is now the case, inasmuch as such a course would enable comparisons to be made between the results arrived at by different observers. Perhaps no arbitrary rules could be enforced; but the Author would suggest that in the preparation of specifications for, and in all tests and observations on the properties of, Portland cement, there should be uniformity of procedure with regard to—1. The degree of mechanical pulverisation to be observed by the manufacturer. 2. The section or form of the test

briquette. 3. The proportion of water used in mixing the cement for testing. 4. The age of the test briquette, for what may be termed the qualifying test. 5. The tensile breaking strain, wet and dry, and at different ages. 6. The tensile strength when mixed with different proportions of sand, and at different ages. 7. The tensile strength of the cement mortar as used in the work. 8. The weight per bushel. 9. The results of tests of each separate manufacture should be kept distinct, and all should be recorded as much as possible in detail. 10. The description of machine to be used for the purpose of testing the tensile strength.

The steelyard weighing-machines generally employed for this purpose are open to the objection, that when the weight is actuated by means of a wheel and screw, it is possible, by traversing the weight too quickly, to overrun the breaking point, thus causing a higher tensile strength to be recorded than the cement is justly entitled to. On the other hand, it has been observed that the effort of turning the actuating gear frequently causes the steelyard bar to oscillate a little above and below the centre horizontal line, which would cause a strain in excess of that recorded on the index to be thrown upon the briquette. With a view of obviating these difficulties, the Author would suggest an application of the hydraulic ram, as being eminently suitable for this purpose. An apparatus upon this principle could be so arranged as to serve the double purpose of testing the resistance to tensile and compressive strain; and, being slower and more uniform in its action, much more trustworthy results would be obtained.

APPENDIX A.

ANALYSIS of RAW MATERIALS USED by the BURHAM CEMENT COMPANY.

Gault Clay—

Silica	46·61
Alumina	16·06
Oxide of iron	6·07
Carbonate of lime	25·06
Magnesia	·60
Potash	·60
Water and organic matter	5·00
	100·00

Grey Chalk—

Carbonate of lime	87·50
Silica	7·00
Alumina	1·15
Magnesia	1·00
Oxide of iron	·30
Organic matter and water	3·05
	100·00

ANALYSIS of PORTLAND CEMENT MANUFACTURED by the BURHAM CEMENT COMPANY.

Alumina	12·25
Oxide of iron	4·30
Magnesia	·30
Pure lime	50·00
Sulphate of lime	2·00
Potash	·85
Soda	·75
Silicic acid	25·00
Clay sand	3·00
Moisture	1·00
Loss	·55
	100·00

ANALYSIS of RAW MATERIALS USED by HOOPER and Co.

Wet Clay—

Carbonate of lime	2·79
Silica	24·86
Alumina	5·12
Oxide of iron	1·08
Potash and soda	1·39
Water	64·76
	100·00

Raw Chalk from the Opening—

Carbonate of lime	76·00
Silica	1·09
Alumina	·73
Oxide of iron	·36
Carbonate of magnesia	·06
Water	21·49
Loss	·27
	100·00

ANALYSIS of PORTLAND CEMENT MANUFACTURED by HOOPER and Co.

Lime	64·36
Silica	26·42
Alumina	6·22
Oxide of iron	1·58
Potash and soda	1·37
Magnesia	·05
	100·00

ANALYSIS of RIVER MUD USED GENERALLY in the MEDWAY DISTRICT in the MANUFACTURE of PORTLAND CEMENT.

Silica	23·60
Alumina	19·20
Oxide of iron	8·80
Carbonate of lime	6·00
Magnesia	1·60
Soda and potash	2·00
Organic matter	18·00
Clay sand	3·00
Water	17·00
Loss	·80
	100·00

[APPENDIX B.

APPENDIX B.

N.B.—In every case the breaking strain is on an area of 2¼ square inches.

TABLE I.—AVERAGE PROPORTION of COARSE CEMENT in EACH MANUFACTURE.

Manufacturer.	Average Weight per Bushel.	Average Weight of Coarse.	Average Weight of Fine.	Proportion.	Percentage of Gross Weight.[1]
	lbs.	lbs.	lbs.		
Booth and Co. . .	114·725	24·000	90·725	1 to 3·780	20·92
Burham Co. . .	113·610	16·000	97·610	1 to 6·100	14·09
Francis and Co. .	118·089	26·500	91·589	1 to 3·456	22·44
Hooper and Co. .	113·325	32·875	80·450	1 to 2·447	29·01
Wouldham Co. . .	118·680	25·125	93·555	1 to 3·723	21·16
Generally . .	115·204	24·900	90·304	1 to 3·626	21·61

[1] Number of parts by weight contained in one hundred, by weight.

TABLE II.—BREAKING STRAIN of CEMENT of LIGHT WEIGHT.

Manufacturer.	Weight per Bushel.	Breaking Strain.
	lbs.	lbs.
Booth and Co. . .	106	828
" " . .	107	909
" " . .	104	792
" " . .	107	901
Burham Co. . . .	108	626
" " . .	106	839
" " . .	105	851
" " . .	105	985
" " . .	108	878
" " . .	108	896
Francis and Co. .	107	871
Hooper and Ashby .	105	740
" " .	106	659
Wouldham Co. . .	107	734

TABLE III.—RESULTS of SECOND TEST of CEMENT AFTER BEING SPREAD OUT and COOLED.

Booth and Co.			Burham Co.			Francis and Co.			Wouldham Co.[1]		
Weight per Bushel.	First Test.	Second Test.	Weight per Bushel.	First Test.	Second Test.	Weight per Bushel.	First Test.	Second Test.	Weight per Bushel.	First Test.	Second Test.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
112	464	901	121	344	776	124	438	541	119	739	983
116	426	933				119	390	550	115	863	1,012
						122	415	625	118	661	1,065
						116	400	648	114	662	901
						112	406	900			
						117	327	748			
						115	416	785			
						112	387	704			
						112	417	874			
						112	405	789			
						112	384	738			
						113	433	720			
						116	284	644			
						116	367	463			
						119	409	595			
						114	377	934			

[1] This cement was supplied to the Admiralty for convict labour, and was specified to have a tensile strength of 350 lbs. on the square inch.

TABLE IV.—TENSILE STRENGTH of PORTLAND CEMENT by WET and DRY TESTS at SEVEN DAYS, ALSO AVERAGE WEIGHT PER BUSHEL.

Manufacturer.	Weight per Bushel.	Wet. Breaking Strain.	Number of Tests.	Dry. Breaking Strain.	Number of Tests.	Quantity.
	lbs.	lbs.		lbs.		tons.
Booth and Co. .	114·7	845·3	162	745·6	162	5,391
Burham Co. .	113·6	789·8	510	734·8	504	18,996
Francis and Co.	118·1	631·4	1,296	657·7	1,284	21,616
Hilton and Co.	112·8	904·6	15	854·8	15	507
Hooper and Co.	113·3	657·3	420	661·7	417	6,001
Wouldham Co.	118·7	859·0	306	829·2	306	10,354
	691·2	4,687·4	2,709	4,483·8	2,688	62,865
Generally .	115·2	781·2		747·3		

TABLE V.—COMPARISON BETWEEN the TENSILE STRENGTH of PORTLAND CEMENT at SEVEN DAYS and THIRTY DAYS.

Manufacturer.	Breaking Strain at Seven Days.	Breaking Strain at Thirty Days.	Number of Tests.	Percentage of Increase.
	lbs.	lbs.		
Booth and Co. . .	837·8	1,045·5	45	24·8
Burham Co. . . .	829·4	1,085·2	44	30·8
Francis and Co. .	673·0	939·2	126	39·6
Hooper and Ashby	684·6	899·2	39	31·3
Wouldham Co. . .	867·4	1,121·2	56	29·3

TABLE VI.—INCREASE in STRENGTH of PORTLAND CEMENT from SEVEN DAYS to TWELVE MONTHS.—Manufactured by BOOTH and Co.

Age.	Seven Days.	Two Months.	Six Months.	Twelve Months.	Remarks.
	lbs.	lbs.	lbs.	lbs.	
Breaking strain .	941 1,046 1,013	900 1,036 1,020	870 990 982	1,150 1,288 1,284	Three tests from same sample, weighing 112 lbs. per bushel.
Sum	3,000	2,956	2,842	3,722	
Average	1,000	985	947	1,241	
Increase in lbs. .	..	..	..	241	
Increase per cent. .	..	..	..	24	

TABLE VII.—INCREASE in STRENGTH of PORTLAND CEMENT from SEVEN DAYS to TWELVE MONTHS.—Manufactured by the BURHAM COMPANY.

Age.	Seven Days.	Two Months.	Six Months.	Twelve Months.	Remarks.
	lbs.	lbs.	lbs.	lbs.	
Breaking strain .	966 956 956	1,130 1,081 1,085	996 1,107 1,202	1,239 1,286 1,211	Three tests from same sample, weighing 114 lbs. per bushel.
Sum	2,878	3,296	3,305	3,736	
Average . . .	959	1,099	1,102	1,245	
Increase in lbs. .	..	140	143	286	
Increase per cent. .	..	14	15	30	

TABLE VIII.—INCREASE in STRENGTH of PORTLAND CEMENT from SEVEN DAYS to TWELVE MONTHS.—Manufactured by FRANCIS and Co.

Age.	Seven Days.	Two Months.	Six Months.	Twelve Months.	Remarks.
	lbs.	lbs.	lbs.	lbs.	
Breaking strain .	590	1,204	1,468	1,624	Three tests from same sample, weighing 112 lbs. per bushel.
	624	1,230	1,542	1,797	
	598	1,288	1,465	1,865	
Sum	1,812	3,722	4,475	5,286	
Average . . .	604	1,241	1,492	1,762	
Increase in lbs. .	..	637	888	1,158	
Increase per cent. .	..	105	147	192	

TABLE IX.—INCREASE in STRENGTH of PORTLAND CEMENT from SEVEN DAYS to TWELVE MONTHS.—Manufactured by HOOPER and ASHBY.

Age.	Seven Days.	Two Months.	Six Months.	Twelve Months.	Remarks.
	lbs.	lbs.	lbs.	lbs.	
Breaking strain .	549	984	1,189	1,441	Three tests from same sample, weighing 114 lbs. per bushel.
	634	1,080	1,307	1,510	
	583	1,085	1,186	1,549	
Sum	1,766	3,149	3,682	4,500	
Average . . .	589	1,050	1,227	1,500	
Increase in lbs. .	..	461	638	911	
Increase per cent. .	..	78	108	155	

TABLE X.—INCREASE in STRENGTH of PORTLAND CEMENT from SEVEN DAYS to TWELVE MONTHS.—Manufactured by the WOULDHAM COMPANY.

Age.	Seven Days.	Two Months.	Six Months.	Twelve Months.	Remarks.
	lbs.	lbs.	lbs.	lbs.	
Breaking strain .	857	1,262	1,387	1,364	Three tests from same sample, weighing 121 lbs. per bushel.
	750	1,188	1,499	1,470	
	900	1,132	1,515	1,631	
Sum	2,507	3,582	4,401	4,465	
Average . . .	836	1,194	1,467	1,488	
Increase in lbs. .	..	358	631	652	
Increase per cent. .	..	43	75	78	

TABLE XI.—COMPARATIVE TENSILE STRENGTH at TWELVE MONTHS.

Booth and Co.	Burham Co.	Francis and Co.	Hooper and Co.	Wouldham Co.
lbs.	lbs.	lbs.	lbs.	lbs.
1,085	1,274	1,601	1,238	1,405
1,193	1,470	974	1,407	1,615
1,535	1,172	1,236	1,446	1,344
1,241	1,264	1,580	1,275	1,283
1,358	1,239	1,575	1,540	1,553
1,368	1,286	1,680	1,308	1,364
1,150	1,211	1,792	1,284	1,470
1,288	1,108	1,446	1,497	1,631
1,284	1,090	1,712	1,516	1,353
952	1,260	1,660	1,396	1,381
1,208	1,400	1,509	1,441	1,334
1,213	1,344	1,624	1,510	1,395
1,456	1,237	1,797	1,549	..
1,365	1,398	1,865	1,232	..
1,512	1,080	1,120	1,129	..
..	1,211	1,181	1,157	..
..	1,587	954	1,284	..
..	1,775	1,456	1,220	..
..	1,176	1,347	1,451	..
..	1,414	1,295	1,125	..
..	1,344	1,334	1,323	..
..	1,071	1,180	1,204	..
..	1,360	1,617	1,237	..
..	1,320	1,498	1,456	..
..	1,533	1,169	1,586	..
..	1,475	1,270	1,428	..
..	1,445	1,502	1,426	..
..	..	1,410	1,422	..
19,208	35,544	40,384	38,087	17,128
1,280	1,316	1,442	1,360	1,427

TABLE XII.—COMPARATIVE TENSILE STRENGTH at TWO YEARS.

Booth and Co.	Burham Co.	Francis and Co.	Hooper and Co.	Wouldham Co.
lbs.	lbs.	lbs.	lbs.	lbs.
985	1,197	1,340	1,366	1,470
951	1,420	1,559	1,463	1,419
1,092	1,466	1,437	1,472	1,269
1,018	1,603	1,679	1,330	1,866
1,104	1,594	1,546	1,473	1,514
938	1,476	1,646	1,309	1,214
983	1,266	1,456	1,494	1,464
1,060	934	1,467	1,320	1,393
1,344	1,585	1,587	1,320	1,502
..	1,196	1,414	1,478	1,316
..	..	1,563	1,358	1,487
..	..	1,430	1,225	1,500
..	..	1,615	..	1,407
..	..	1,549	..	..
9.475	13,737	21,288	16,608	18,821
1,053	1,374	1,521	1,384	1,448

TABLE XIII.—BREAKING TENSILE STRAIN of PORTLAND CEMENT in RELATION to WEIGHT.—Manufactured by BOOTH and Co.

Weight in lbs. per bushel.							
112	113	114	115	116	117	118	119
Breaking tensile strain.							
906	..	644	797	538	..	728	1,002
772	..	657	693	723	..	1,076	816
901	..	892	899	847	..	1,191	934
977	..	890	1,071	698	..	606	978
1,000	..	904	700	697	..	985	607
994	..	935	818	703	..	756	662
887	..	..	720	806	..	911	..
794	..	..	..	1,101	..	895	..
828	..	..	..	..	..	..	..
709	..	..	..	..	..	..	..
856	..	..	..	..	..	..	..
896	..	..	..	..	..	..	..
874	..	..	..	..	..	..	..
11,394	..	4,922	5,698	6,113	..	7,148	4,999
876	..	820	814	764	..	893	833

NOTE.—In Tables XIII. to XVI. the breaking tensile strains recorded under the respective weights per bushel are, in each case, the average results of three tests.

Table XIV.—Breaking Tensile Strain of Portland Cement in relation to Weight.—Manufactured by the Burham Company.

Weight in lbs. per bushel.								
112	113	114	115	116	117	118	119	120
Breaking tensile strain.								
517	620	560	598	603	678	632	809	684
570	613	709	505	707	578	676	751	724
585	613	850	735	642	655	923	689	606
662	630	696	670	619	557	1,028	768	546
630	606	907	1,068	914	932	836	754	734
736	724	799	1,007	754	746	790	893	..
692	1,040	793	626	827	883	..	480	..
689	874	927	488	865	918	..	..	..
594	888	1,010	469	947	..	..	..	..
906	703	1,060	947	1,030	..	..	..	..
752	858	959	1,032	948	..	..	..	..
611	908	759	818	800	..	..	..	..
1,012	575	929	981	822	..	..	..	..
488	876	..	..	..	..	..	..	..
798	891	..	..	..	..	..	..	..
760	1,038	..	..	..	..	..	..	..
898	726	..	..	..	..	..	..	..
965	..	..	..	..	..	..	..	..
863	..	..	..	..	..	..	..	..
684	..	..	..	..	..	..	..	..
688	..	..	..	..	..	..	..	..
782	..	..	..	..	..	..	..	..
756	..	..	..	..	..	..	..	..
937	..	..	..	..	..	..	..	..
759	..	..	..	..	..	..	..	..
925	..	..	..	..	..	..	..	..
683	..	..	..	..	..	..	..	..
738	..	..	..	..	..	..	..	..
702	..	..	..	..	..	..	..	..
850	..	..	..	..	..	..	..	..
22,232	13,183	10,958	9,944	10,478	5,947	4,885	5,144	3,294
741	775	843	765	806	743	814	735	659

TABLE XV.—BREAKING TENSILE STRAIN of PORTLAND CEMENT in RELATION to WEIGHT.
Manufactured by FRANCIS and Co.

Weight in lbs. per bushel.															
112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127
Breaking tensile strain.															
614	541	479	434	608	444	754	445	529	543	674	474	506	596	567	459
500	405	469	454	540	469	589	475	514	570	369	520	534	471	476	509
639	560	463	478	500	476	476	504	557	482	545	550	483	541	629	626
531	620	590	643	617	499	567	478	470	460	464	480	470	656	570	670
900	660	664	511	563	459	557	567	612	623	533	600	457	546	592	528
850	449	481	593	677	607	525	550	506	574	526	627	540	473	561	..
704	636	733	519	648	655	523	645	596	486	535	673	506	530	608	..
552	814	488	691	685	636	551	477	591	535	528	598	541	..	645	..
671	639	661	619	566	594	613	589	585	595	701	601	554	..	775	..
634	495	789	567	516	658	522	668	559	654	656	632	557	..	..	..
728	562	714	537	544	482	546	567	549	571	616	686	614	..	..	..
874	535	679	592	769	755	591	568	636	672	653	657	611	..	..	..
672	601	862	595	869	660	672	536	778	735	521	..	658	..	..	..
749	623	644	785	940	614	508	665	644	841	538	..	656	..	..	..
613	..	709	663	927	614	695	566	716	641	625	..	671	..	..	..
574	..	506	586	626	695	676	490	760	756	564	..	671	..	..	..

592	..	742	555	803	624	597	760	648	797	738	..	961	..	..	..
510	..	642	703	477	603	643	729	739	586	754	..	..	..	..	..
738	..	563	629	510	585	601	702	715	786	723	..	..	..	..	..
671	..	480	504	552	568	630	674	905	795	673	..	..	..	..	..
856	..	588	440	697	748	579	626	802	675	710	..	..	..	..	..
775	..	500	654	505	724	613	771	1,014	718	759	..	..	..	..	..
..	..	437	779	644	869	744	707	715	627	508	..	..	..	..	..
..	..	727	799	463	774	732	779	654	..	514	..	..	..	..	..
..	..	739	660	741	602	726	595	590	..	..	..	..	..	..	..
..	..	874	611	668	638	624	976	605	..	..	..	..	..	..	..
..	..	672	..	762	458	783	610	609	..	..	..	..	..	..	..
..	..	634	..	728	550	963	630	474	..	..	..	..	..	..	..
..	..	643	..	800	691	848	643	687	..	..	..	..	..	..	..
..	..	..	..	692	475	800	595	695	..	..	..	..	..	..	..
..	..	..	..	614	832	828	848	854	..	..	..	..	..	..	..
..	..	..	..	892	703	987	817	..	..	..	..	..	..	..	..
..	..	..	..	..	548	590	789	..	..	..	..	..	..	..	..
..	..	..	..	..	858	502	..	..	..	..	..	..	..	..	..
..	..	..	..	..	576	542	..	..	..	..	..	..	..	..	..
..	..	..	..	..	551	700	..	..	..	..	..	..	..	..	..
..	..	..	..	..	619	676	..	..	..	..	..	..	..	..	..
..	..	..	..	..	598	905	..	..	..	..	..	..	..	..	..
..	..	..	..	..	620	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	671	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	894	..	..	..	..	..	..	..	..	..	..
14,947	8,140	18,172	15,601	21,143	25,696	24,978	21,041	20,308	14,722	14,427	7,098	9,990	3,813	5,423	2,792
679	581	627	600	661	627	657	638	655	640	601	591	588	545	603	558

TABLE XVI.—BREAKING TENSILE STRAIN of PORTLAND CEMENT in RELATION to WEIGHT.—Manufactured by the WOULDHAM COMPANY.

Weight in lbs. per bushel.										
114	115	116	117	118	119	120	121	122	123	124
Breaking tensile strain.										
805	717	796	1,083	807	638	1,063	731	940	1,002	856
878	821	816	668	890	830	956	950	1,061	935	604
662	977	748	715	794	948	962	890	1,120	969	503
901	871	712	789	661	807	1,066	970	788	820	677
848	906	700	1,107	762	742	947	1,132	964	..	812
..	800	812	1,138	945	961	953	860	1,149	..	739
..	716	966	..	1,058	1,037	846	835	930	..	966
..	958	809	..	703	953	1,081	600	943	..	..
..	863	1,005	..	791	744	812	690	868	..	..
..	794	792	..	872	..	..	805	994	..	..
..	..	814	..	1,187	..	..	..	1,002	..	..
..	..	..	..	888	..	..	..	1,005	..	..
..	..	..	..	749	..	..	..	911	..	..
..	..	..	..	1,065	..	..	..	..	..	..
4,094	8,423	8,970	5,500	12,172	7,660	8,686	8,463	12,675	3,726	5,157
819	842	815	917	869	851	965	846	975	931	737

TABLE XVII.—INCREASE in TENSILE STRENGTH of CEMENT and SAND in the PROPORTION of 1 of CEMENT to 2 of SAND.

Age.	November 10, 1869. Tensile Strain.	Increase.		December 16, 1870. Tensile Strain.	Increase.	
Months.	lbs.	lbs.	Per cent.	lbs.	lbs.	Per cent.
Six	575	..	..	654	..	..
Seven	570	..	..	1,001	347	53
Eight	669	94	16	984	330	50
Nine	755	180	31	Omitted.	..	..
Ten	755	180	31	1,042	388	59
Eleven	844	269	47	1,169	515	79
Twelve	911	336	58	1,240	586	90

TABLE XVIII.—INCREASE in TENSILE STRENGTH of NEAT CEMENT; also CEMENT and SAND in DIFFERENT PROPORTIONS, at SEVEN DAYS, TWENTY-EIGHT DAYS, and TWELVE MONTHS; all MIXED from the SAME SAMPLE.—Manufactured by FRANCIS and Co.

Age.	Neat Cement. Breaking Strain.	Increase.		Percentage of Neat Cement at Twelve Months.	1 of Cement to 1 of Sand. Breaking Strain.	Increase.		Percentage of Neat Cement at Twelve Months.
	lbs.	lbs.	Per cent.		lbs.	lbs.	Per cent.	
Seven days	534	..	..	..	353	..	..	..
Twenty-eight days	833	299	56	..	433	80	23	..
Twelve months	954	420	79	..	758	405	115	79
	1 of Cement to 1½ of Sand.				1 of Cement to 2 of Sand.			
Seven days	291	..	..	..	187	..	..	..
Twenty-eight days	294	3	1	..	226	39	21	..
Twelve months	606	315	108	64	562	375	201	59
	1 of Cement to 2½ of Sand.				1 of Cement to 3 of Sand.			
Seven days	122	..	..	..	..	..	..	..
Twenty-eight days	178	56	46	..	158	..	..	..
Twelve months	411	289	237	43	356	198	125	37

TABLE XIX.—TENSILE STRENGTH of PORTLAND CEMENT MIXED with SEA-WATER, FROM ONE MONTH to TWO YEARS.

One Month.	Two Months.	Three Months.	Two Years.
lbs.	lbs.	lbs.	lbs.
544	847	1,155	1,264
616	844	1,151	1,456
592	838	1,206	1,463
551	904	1,185	1,268
711	794	1,237	1,620
630	807	1,008	1,020
666	900	1,155	1,547
890	1,060	1,051	1,095
846	1,036	960	1,576
719	1,132	975	1,476
772	1,178	1,062	1,522
823	1,179	1,049	1,225
720	1,193	1,034	1,584
896	1,070	1,045	1,380
9,976	13,782	15,273	19,496
713	984	1,091	1,393

TABLE XX.—TENSILE STRENGTH of PORTLAND CEMENT, SCREENED and UNSCREENED, at ONE MONTH.

Manufacturer.	Fine. Screened.	Coarse. Unscreened.	Remarks.
	lbs.	lbs.	
Booth and Co. . . .	836	995	Four separate samples from
Burham Co.	1,019	1,183	each manufacturer: three
Francis and Co. . . .	554	761	tests from each sample:
Hooper and Co. . . .	722	763	twelve tests in each case.
Wouldham Co. . . .	1,082	1,204	Kept in water till tested.

TABLE XXI.—TENSILE STRENGTH of PORTLAND CEMENT, SCREENED and UNSCREENED, NEAT, and also MIXED with SAND in the PROPORTIONS of 1 to 1, and 2 to 1, at ONE MONTH and THREE MONTHS.

Neat.		1 to 1.		2 to 1.		Remarks.
Fine.	Coarse.	Fine.	Coarse.	Fine.	Coarse.	
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
1,165	1,113	627	458	376	399	One month in water.
1,061	1,085	726	560	302	378	
1,167	1,179	626	586	465	483	
1,275	1,183	686	614	474	399	
1,323	1,186	681	588	476	290	
1,077	1,204	700	560	572	404	
1,109	1,248	599	577	396	455	
8,177	8,198	4,645	3,943	3,061	2,808	
1,168	1,171	664	563	437	401	

TABLE XXII.

Neat.		1 to 1.		2 to 1.		Remarks.
Fine.	Coarse.	Fine.	Coarse.	Fine.	Coarse.	
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
1,438	1,582	916	632	740	577	Three months in water.
1,466	1,200	969	770	702	584	
1,616	1,211	915	990	695	574	
1,435	1,586	892	825	666	560	
1,585	1,356	905	788	704	560	
1,383	1,582	920	..	796	560	
1,375	1,589	966	..	..	553	
10,298	10,106	6,483	4,005	4,303	3,968	
1,471	1,444	926	801	717	567	

Table XXIII.

Neat.		1 to 1.		2 to 1.		Remarks.
Fine.	Coarse.	Fine.	Coarse.	Fine.	Coarse.	
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
1,265	1,466	1,265	1,021	1,001	794	Six months in water.
1,252	1,498	1,158	1,029	872	850	
1,241	1,447	1,219	1,023	875	745	
1,208	1,286	1,018	1,031	814	784	
1,288	1,389	1,082	1,120	947	801	
1,252	1,396	1,277	1,167	915	796	
1,284	1,277	1,250	1,204	840	786	
8,790	9,759	8,269	7,595	6,264	5,556	
1,256	1,394	1,181	1,085	895	794	

Table XXIV.

Neat.		1 to 1.		2 to 1.		Remarks.
Fine.	Coarse.	Fine.	Coarse.	Fine.	Coarse.	
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
832	874	525	469	327	283	One month in water.
751	794	439	472	291	262	
879	776	388	403	283	280	
787	778	440	448	290	247	
728	885	469	356	315	257	
672	834	448	432	303	329	
801	888	..	400	336	259	
5,450	5,829	2,709	2,980	2,145	1,917	
779	833	451	426	306	274	

TABLE XXV.

Neat.		1 to 1.		2 to 1.		Remarks.
Fine.	Coarse.	Fine.	Coarse.	Fine.	Coarse.	
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
732	920	730	812	376	356	Three months in water.
906	1,027	628	762	437	384	
988	991	633	588	412	364	
1,008	1,056	687	748	440	343	
786	971	719	800	397	340	
896	896	668	766	425	346	
880	1,078	686	700	455	347	
6,196	6,939	4,751	5,176	2,942	2,480	
885	991	679	739	420	354	

TABLE XXVI.

No. of Test.	1 to 1.		Remarks.
	Fine.	Coarse.	
	lbs.	lbs.	
1	910	707	Three months in water.
2	1,000	722	
3	991	616	
4	847	703	
5	1,010	740	Cement taken from bulk as deposited in the store.
6	913	722	
7	1,013	672	
8	801	616	
9	920	682	
10	1,032	695	
11	1,043	696	
12	819	684	
13	820	685	
	12,119	8,940	
Average . .	932	688	

TABLE XXVII.

Proportion.	Seven Days.	Three Months.	Six Months.	Remarks.
	lbs.	lbs.	lbs.	
1 water to 3 cement .	1,036	1,508	1,544	Breaking tensile strain. Kept in water till tested.
1 water to 2½ cement .	804	1,314	1,278	
1 water to 2 cement .	637	1,161	1,094	

No. 1,415.—"On the Use of Fascines in the Public Works of Holland." By THOMAS COLCLOUGH WATSON, M. Inst. C.E.

HOLLAND, from its geographical position, is exposed both to damage from the sea and to internal inundation. Lying at the outlet of the rivers Rhine and Meuse, for a great part many feet below low water, the inhabitants have been engaged for centuries in a continued contest with the waters. In this struggle the Dutch have had to contend with no ordinary difficulties: their country produces no stone, timber, or other material usually employed in great hydraulic works; while the soil is composed of soft alluvium, brought down by the rivers, and deposited on a base of sand which formed originally the bed of the ocean.

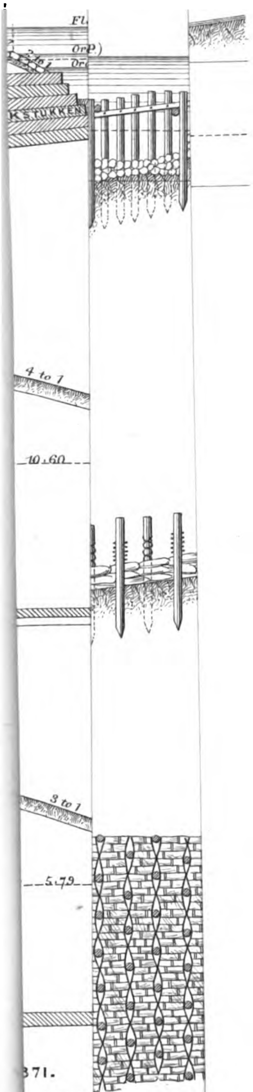
While Holland produces none of the materials referred to, its swamps and morasses are admirably suited to the growth of the willow, alder, aspen, and brushwood of analogous character. This has been taken advantage of; hence nearly all the vast protective works of the country derive their strength from the judicious employment of fascines. The object of this Paper is to show how, with their aid, the Dutch have succeeded in protecting their country, not only from internal inundation, but from the ravages of the ocean itself.

FASCINES,

Called in Dutch 'Ryshout,' are derived from copses of willows, osiers, &c., on the low lands and islands in the estuaries of the Rhine and the Meuse. Willow, with a small admixture of ash and alder, is grown as a business, the crop being cut every third or fourth year.[1] The wood is cut early in the autumn as a rule, but in cases of extraordinary demand in the spring. The cutters are careful to leave the stub, or root, with an oblique upper surface, having its highest point towards the north; neglect of this precaution is said greatly to lessen the succeeding crop.

There are several sorts of ryshout: Hollandsche, Brabantsche, Geldersche, Limburgsche, Schornesche, and Gasterlandsche, so

[1] A hectare (2½ acres) will produce about four thousand to five thousand bundles of fasines, besides stakes and hoop wood.



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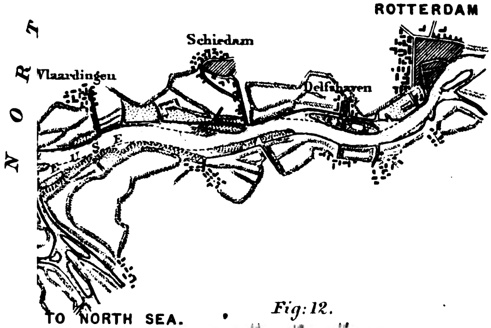
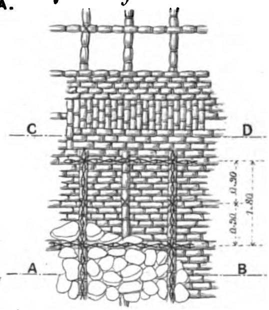
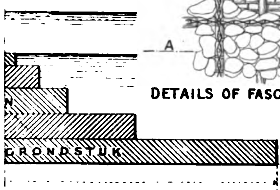


Fig: 12.

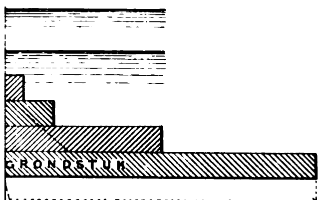


DETAILS OF FASCINE MATTRASSES.



Scale for Figs 10 & 11. 0·03 = 1M. (1/300)

Scale for Figs 12, 13 & 14. 0·06 = 1M. (1/150)



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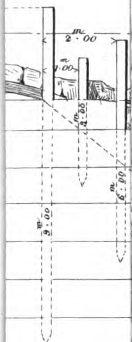
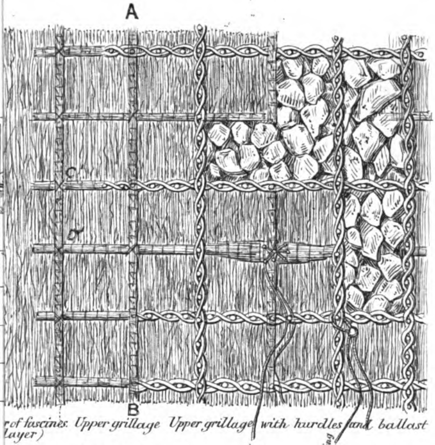


JETTY.



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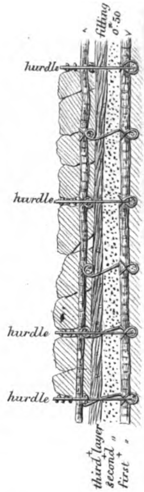
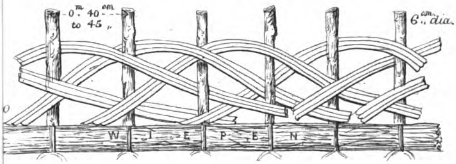


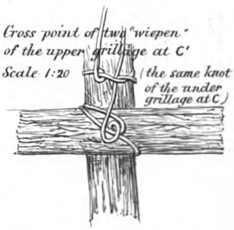
CROSS SECTION AT A B



ELEVATION OF "TUIN"

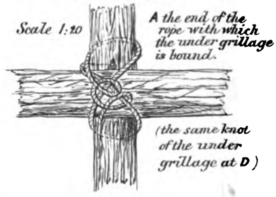
Cross point of two "wiepen" of the upper grillage at C'

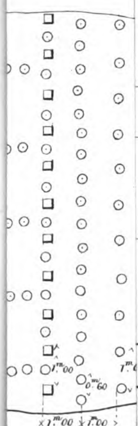
Scale 1:20

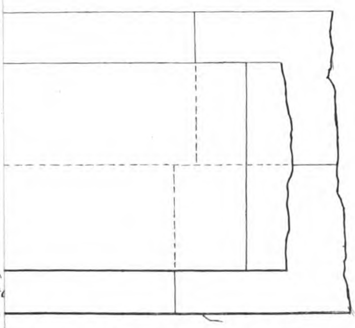


Cross point of two "wiepen" of the upper grillage at D

Scale 1:20







SES OVERLAPS THE FIRST COURSE.

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called from the different provinces where the wood is grown. Fascines of oak and hazel are procured from the higher districts, but the wood generally used is willow.

'Hollandsche ryshout' is of this latter wood, very full of small branches and twigs, the main sticks growing tolerably straight and parallel. The largest are used for cask-hoops; the smaller are cut and tied in bundles. Each bundle contains at least three sticks 9 feet 10 inches to 11 feet 6 inches long, and two of 6 feet 7 inches to 8 feet 2 inches; the twigs and smaller branches remaining attached to the sticks, which are about 1¼ inch in diameter at the root end. If the branches are insufficient, more brushwood is added; the whole is bound round with two osiers, one being about 1 foot from the thick end, the other 3 feet from the top; the bundle, when complete, should measure about 17 inches in circumference at the thick end, and about 14 inches at the other. These faggots form the great base of all fascine operations; and their cost is from 5*s.* to 7*s.* per hundred according to demand. Fascines should be used within a year of their being cut; if kept longer they lose much of their strength and toughness.

'Haring band,' or 'Tuin latten,' are sticks of about ¾ to 1 inch in diameter, without twigs or branches, made up in bundles of twenty-five; they are straight, tough willow, and their cost is from 22*s.* to 30*s.* per hundred bundles.

'Hollandsche garden,' or latten, resemble the former, except that the branches are allowed to remain; they are thinner and longer —8 feet 10 inches to 9 feet 10 inches—made up in bundles of forty each, secured by osiers.

'Wiepbanden,' 'Kruisbanden,' and 'Knÿpbanden,' are osiers to be used as withes or binders; they are respectively 4 feet 3 inches, 5 feet 3 inches, and 6 feet 7 inches long, and their cost is from 3*s.* to 6*s.* per thousand.

'Palen,' or 'Staken,' are stakes of willow or alder, about 6 inches in circumference in the middle, 4 feet 5 inches long, and have a sharp three-cornered point; these are made up in bundles, containing ten each, at 24*s.* to 30*s.* per hundred bundles.

'Slieten' are heavier stakes than the foregoing, being 7 inches in circumference, and 7 feet 3 inches long.

'Dyk horden' are close wattled hurdles, consisting of thirteen vertical equidistant stakes, interwoven with pliable willow sticks about ¾ inch in diameter.

The above completes the list of Hollandsche 'ryshout'; that derived from other provinces is of much the same description, dif-

fering only in an admixture of oak, hazel, ash, and other brushwood.

Oak piles, called 'Perkoen palen,' are also used in fascine works; they are about 5 feet 3 inches long, and 1 foot in circumference in the middle. Two sorts of reeds are used in protecting slopes from the wash of water under fascines: 'Groenriet,' cut when green, called also 'Bladriet,' made into bundles 8 feet 2 inches long and 2 feet in circumference; and 'Dekriet,' cut when come to maturity, made up into bundles 6 feet 7 inches to 9 feet 10 inches long, and 3 feet 3 inches in circumference.

The materials above described are all produced in the country; but as large quantities of stone are required on nearly all fascine works, either as ballast to submerge the fascine mattrasses, or as paving on slopes permanently exposed to wash, basalt from the Rhine is chiefly used, while Norwegian granite and Belgian limestone are also employed.

HOW THE FOREGOING MATERIALS ARE MADE USE OF.

The duties of the Dutch engineers, so far as protective works are concerned, consist mainly in constructing, with the foregoing materials, dams to restrain rivers within certain channels; to protect slopes or foreshores; to dam off river branches, or tidal estuaries, and to reclaim land. As an instance of the latter, the following description is given of the mode adopted in closing an estuary of the Zuiderzee, east of Amsterdam, called 'Het Y,' under the Author's supervision:—The width at the point selected for the construction of the dam was 1,367 yards, about ¾ mile; the depth of water varying from 5 feet to 27 feet. The bottom was soft alluvium, about 40 feet deep, reposing on sand. There was a rise and fall of tide of about 14 inches; but variations in level from storms reached 10 feet to 15 feet, at which times the current was 2½ miles per hour, although usually not more than half that velocity. At 328 yards from the northern end, locks and sluices were constructed in the body of the dam, taking up about 394 feet of its length. A transverse section of the dam is represented in Plate 11, Figs. 1 and 2. The following is an extract from the specification: "The crown of the dam is to be 13·1 feet broad, rounded 9·8 inches, carried to 12·3 feet above A.P. (Government standard level, called Amsterdamsche Peil, being the datum of reference all over the Netherlands); the external slope facing the sea to be 3½ to 1 to 1·64 foot above A.P., and the internal slope to be 2 to 1 to the same level; then a horizontal berm 9·8 feet wide

on the outside, and another 16·4 feet wide on the inside, and next slopes of 2 to 1 to 1·64 below A.P.: if fascines are used, slopes below this level to be ¾ to 1.

"The slopes, berms, and crown are to be covered with puddled clay 3·28 feet thick; both sides to be protected with strong fascine works from the top to 1·64 foot below A.P., and loaded with stone. When the dam is closed, the fascines on the inside and outside slopes are to be removed; a bed of broken bricks, 0·66 foot thick, is to be placed on both slopes, and the surfaces paved to 1·64 foot below A.P., with stone at least 1 foot thick."

In commencing the construction of the dam (dyke, in Dutch), the first step was to cover the entire site with a strong fascine mattrass, worked in pieces 197 feet long, and overlapping each other about 3 feet 3 inches, called 'grondstukken'; then to build up the exterior dams entirely of fascines to low-water level, nearly filling the trough or hollow between them with sand or clay.

As fascines under water are nearly always used in the form of 'grondstukken' or 'zinkstukken,' a detailed account of their construction is necessary.

The first requisites for a 'grondstuk' are the 'wiepen' (Plate 12); these are ropes of fascines, which form a network above and below the grondstuk, constructed as follows:—The workman drives two stakes into the ground, about 2 feet 6 inches apart, to which he secures a cross stick about 2 feet 3 inches from the ground. A series of these frames are erected about 2 feet apart, the number being dependent on the size of the grondstuk and consequent length of the rope, or wiep. The stage being ready, those bundles of fascines with most branches and twigs are opened and the contents placed on the cross sticks of the stage, the fascines being drawn out lengthways, so that each bundle overlaps and bonds well into the next. They are laid of such thickness that, on being bound round in the form of a rope, the circumference is 17 inches. When the full length for one wiep has been laid out, they are tied with osier bands, 'knÿpbanden,' at intervals of 1 foot 3 inches. The bands are tightly twisted and the ends tucked under like a faggot band. Lighter intermediate bands, 'wiepbanden,' are then put on about 4 inches apart, and the rope, or wiep, is ready. The wiepen are now laid out on the ground in parallel rows 2 feet 6 inches to 3 feet 3 inches apart, to the full width of the proposed mattrass. These are crossed by a second layer at right angles to the first, thus forming a network with meshes 2 feet 6 inches to 3 feet 3 inches square, the exact size of the projected grondstuk.

The site for making the grondstuk should be between high and low-water mark, for convenience of subsequent floating; they are, however, frequently prepared on the surface of the water. Every alternate crossing of the wiepen is securely tied with ½-inch tarred rope, the ends of which are left about 4 feet long, and temporarily secured to stakes thrust vertically in the wiepen. The other crossings are secured by 'kruisbanden' of withe. The crossings on the two external rows are generally lashed with rope.

The lower network, being now complete, is covered with a layer of ryshout one bundle thick; a second course is laid across the lower one, and a third at right angles to the second, the three layers being about 18 inches thick. A corresponding network of wiepen is next laid on, and fastened to the lower by the rope ends described as being left over, and they are secured to temporary stakes.

In order to sink and hold the mattrass, it is loaded with a bed of stone. To prevent this rolling to one side in sinking, or on a sloping bottom, the upper surface of the grondstuk is thus divided into rectangular cells: stakes, 'palen,' are driven into the crossings of the wiepen and all round the edge of the grondstuk; between these 'tuin latten' are interwoven or wattled three sticks together. When the wattles are about 7 to 9 inches high, the palen are driven down into the mattrass, the ends remaining about 6 inches above the wattle-work, called 'tuinen,' the cells formed by which serve not only to retain the ballast in place, but add greatly to the strength of the grondstuk.

The 'proppen' are mooring posts, by which the grondstuk is towed to its destination, and held by cables and anchors before sinking. The position of these is decided on when the lower wiepen are being laid, and always at a crossing. The wiepen are there worked much thicker, and securely bound with tarred cord on each side of the crossing, as well as to the upper wiepen. A large and heavy stake is now driven through the mattrass, and six or seven others in a sloping direction, radiating from the centre one. The wiepen are sometimes strengthened at the crossing by a bundle of tuin latten being lashed to the wiepen at the crossing, instead of being thickened. The proppen so secured cannot give way without tearing the grondstuk. The mooring cables are simply turned two or three times round the proppen, so as to be easily cast off when the grondstuk is sunk.

The mattrass, now ready for submersion, is towed to its place and loaded with stone so as just to float. Anchors are placed on all sides, as many as may be necessary to retain it (dependent on

the velocity of the current), the time chosen being about half an hour before the turn of the tide. Small vessels of from 10 to 15 tons burthen are secured to the edges of the grondstuk by ropes running under the upper wiepen, both ends being fast on board the barge; other vessels, with fresh supplies of stone, being kept in reserve outside. The ballast is first carried by men standing on the mattrass towards the centre pockets, and worked towards the outer edges. When the mattrass begins to sink in the centre, and the strain on the supporting ropes becomes severe, a halt is called for a few minutes, while the crews of the barges pile up the remaining cargo on the side of the ship towards the mattrass. This weight, with the tension on the ropes, gives the boats a considerable list; but, being built of great beam, and stout, they resist. At a given signal every captain stands by the supporting rope; and at a second signal, all the ropes are let go simultaneously, the crews throwing out the stone as rapidly as possible, to keep down the outer edges of the grondstuk, which might otherwise be turned and rolled up by the current. The vessels meet near the centre of the mattrass, which now lies on the bottom. The ballasting proceeds until a load of about 3½ cwt. to 7 cwt. per square yard has been deposited as nearly as possible over the whole surface.

'Zinkstukken' are made and sunk in a similar manner, the difference being merely in name. The first zinkstuk is that which reposes on the bottom, hence called 'grond,' or ground piece, The successive layers are called 'zink,' or sinking pieces.

The grondstukken are made to overlap each other lengthways. Those used in the Amsterdam dyke were 2 feet 6 inches in thickness. Including stone, the cost was as under, per metre:—

	Fl. Cents.	s. d.
Twenty bundles fascines at 4·50 f.	0 90	1 6
Thirteen stakes, ⅓ bundle latten	0 11½	0 2¼
Wiep and kruis bands	0 5	0 1
Spun yarn, or tarred rope	0 5	0 1
Labour, making, and sinking	0 16½	0 3¼
	1 28	2 2

To which must be added the cost of the stone, 200 kilogrammes (nearly 4 cwt.) of basalt 1*s*. 8*d*., raising the whole to about 3*s*. 3*d*. per square yard. Prices have, however, augmented since the dam was made in 1866; the same work would now cost at least 4*s*. 3*d*. per square yard.

Although the substratum of fascines will not prevent sinking in soft ground, this takes place regularly and gradually; but danger

is incurred by the possibility of the grondstuk being too weak to carry the weight of the bank in the centre of its cross section, and in consequence being torn asunder longitudinally. When this happens—as it did in the case under consideration—there is nothing to be done but to add material until a solid bottom is reached. The bank, on splitting lengthways, the two parts being supported by the halves of the torn grondstuk, move laterally, as the cavity in the centre is filled and sunk. It was at first intended to have used a double grondstuk; but the idea was abandoned from the fear of water penetrating the bank between the fascines. In sandy ground there is no danger of this, as in a few days the sand completely chokes up the interstices, and a solid bank is the result.

From an examination of the cross section of the dam (Plate 11, Figs. 1 and 2), it will be apparent that working up the two side dams, from the bottom to near the surface of the water, by successive layers of fascine mattrasses, was a simple and easy method of closing the water-way. The last length of 328 yards of opening was raised over the whole distance simultaneously. Further, the material of the core, chiefly sand, was contained securely, none being washed away by the current. Many instances can be adduced where this mode of working has been most successful: at the Sloe, a branch of the Scheldt, for the passage of the Flushing railway (Plate 11, Figs. 3 and 4); the approaches to the great Moerdÿk bridge; and many places on the Lower Rhine, in all which cases a rapid current and considerable variation of tidal level were encountered.

In some instances, where the bottom is firm (as on sand), and the bank only much exposed on one side, no grondstuk is used, and only one lateral dam worked up chiefly for convenience of closing, and to prevent the stuff forming the body of the dam being washed away by the current during construction.

Protecting Slopes or Foreshores.

These coverings are either temporary or permanent. The former are of four kinds, viz.: 'Krammatten,' 'Bladriet,' 'Rysbeslag,' and 'Hangstukken.'

A 'krammat,' used on slopes or berms above low-water level where the wash is not great, is made of wheat or rye straw combed out straight and spread closely over the surface up and down the slope in a layer of about 1 inch to 1½ inch thick. This is kept in place by well-twisted straw bands, 'bengels,' about 4 inches in circumference, laid at right angles to the straw, and thrust into

the ground at intervals of 4 inches to 6 inches, with a blunt fork called a 'kram,' to about 7 inches in depth. The straw bands are about 2 feet apart. The cost of this protection is rather more than 2*d.* per square yard, and it will last about a year.

'Bladriet' protection is made by covering the ground with reeds (cut when green) to a depth of 4 inches; across the reeds lines of pegs are driven and wattled with 'latten,' as in the 'tuinen' of the 'grondstukken'; the lines of tuinen are 2 feet 10 inches apart. This covering is used for slopes likely to be covered by a few extraordinary high floods in the course of a winter. It lasts about a year; the cost is 5*d.* per square yard inclusive of labour and materials.

'Rysbeslag' is used on slopes above low water, and is the strongest of the temporary protections. Reeds are first laid horizontally along the slope or berm 1 inch in thickness, then at right angles a layer of fascines 5 inches thick; across these again stakes are driven and tuinen are interwoven, the rows of tuinen being about 2 feet apart. The whole surface is then covered with heavy stones, about 8½ cwt. per square yard. The cost without stone is 10*d.* per square yard; it will last three or four years.

'Hangstukken' are fascine mattrasses like 'zinkstukken,' but thinner, sunk on slopes under water and heavily laden with stone. They last for many years, and are used as well for permanent as for temporary protection.

Permanent protections are of three kinds:—'Hangmatten' (just described), brick and stone paving.

Brick paving is only used in sheltered situations; the bricks are set in a bed of sand, sometimes on edge and sometimes on end.

Stone paving is the covering employed on all the exposed slopes of the main dams. A bed of good well-worked clay, usually 3 feet 3 inches thick and watertight, is spread over the slope; this is covered by a layer of broken bricks; then comes the paving of stone 1 foot thick, generally basalt, granite (from Norway), or Belgian limestone. The stones are not dressed; the workman selects those that will fit together without leaving large joints; about 1 cwt. is used per square yard of slope. Should the slope have no horizontal berm at the foot, 'perkoen palen' or heavy oak stakes are driven along the toe about 1 foot apart. In very exposed situations groynes of fascines are run out, laden with stone, to protect the pitching from being undermined. The cost of this last species of protection is about 6*s.* 8*d.* per square yard.

Such then are the uses to which fascines are applied in Holland. It remains only to notice the extraordinary skill of the workmen,

chiefly natives of Zealand, called 'rÿs-werkers,' who make this class of work their peculiar occupation. Twenty men will construct a 'zinkstuk' 200 feet long and 60 feet wide in four days; the sinking, if all goes well, occupies about two hours.

As recent examples of fascine works, cross sections are given of

1. Great dam Schellingwoude, near Amsterdam.
2. Section of the dam carrying the railway across the Sloe, a branch of the Scheldt (Plate 11, Figs. 3 and 4).
3. Section of the embankments 'Hollandsche Diep,' forming approaches to the Moerdÿk bridge (Plate 11, Fig. 5).
4. Sketch of the protection to the shore at West Kapelle, Zealand (Plate 11, Figs. 6, 7, and 8).

Piers or Moles in the Open Sea.

The foregoing description has reference generally to internal works, or mere foreshore defences. Emboldened by the success and durability of hydraulic works constructed with fascines, Dutch engineers have within the last ten or fifteen years determined to try how jetties, or moles similarly constructed, and carried out 1,100 yards or 1,650 yards from the shore, will resist the action of waves. In 1862 Government resolved to provide Rotterdam with a better channel to the sea; to which end, the peninsula called the 'Hoek van Holland' has been cut through (Plate 11, Fig. 9). At this spot the coast is of sand to an unknown depth, sloping gradually seaward at the rate of 1 in 150 to 1 in 200, so that a depth of 26 feet below low water is only attained at a distance of from 4,000 to 5,000 feet from low-water mark. Two piers (984 yards apart) are now being made—the northern pier overlaps the southern in order to protect the entrance from the heavy surf raised by north-west winds. A narrow channel has been dredged to about 10 feet below low water between the moles, but the depth required is to be attained and preserved principally by the scouring action of the river Meuse, which, being partly cut off by the dam across the 'Scheur' from its ancient outlet, is driven through the new channel, and so far has carried away more than 6,540,000 cubic yards of sand, the stuff removed by dredging being only about 2,000,000 to 2,600,000 cubic yards. Ships drawing 12 feet to 14 feet of water already use the new cut, which, however, is far from being completed.

The moles (Plate 11, Figs. 10 and 11) are formed chiefly of fascines, and so far have been successful. The work was commenced in 1863; the northern pier is completed to a length of 2,078 feet from the shore; the southern pier is quite finished, the length being 1,258

yards, the extremity terminating in a depth of 16 feet 5 inches at low water.[1] Hitherto the works have suffered comparatively trifling damage from the sea, which is at times very rough. It remains yet to be seen how far the brushwood, of which the fascines are composed, will be affected by the sea-worm and general decay.

The piers are constructed of successive layers of zinkstukken weighted with about 10 cwt. of stone per square yard. The mattrasses are 54·7 yards long by 26·2 yards broad, and 1 foot 8 inches thick without the stone. The entire cost, when deposited in place, stone included, is 11*s.* 3*d.* per square yard, this high price resulting from the risk and difficulty of sinking such large masses in the open sea. The body of the pier takes from five to six mattrasses, averaging, with the stones, about 3 feet 3 inches thick: these are further held in place by five rows of piles driven about 11 feet or 12 feet through the mass into the sand below. The outer slopes and edges of the mattrasses are covered with a coating of stone averaging 13 cubic feet per lineal foot of pier. The part above water is covered with larger stones, retained by rows of small oak piles, the ends of which project above the level of the work, with a view of breaking the force of the waves.

The crown of the southern pier is 26 feet 3 inches wide, rounded on the upper surface, which attains the level of ordinary high water. The piles connecting the mattrasses are carried to a height of 9 feet 10 inches above the top of the piers (*i.e.* ordinary high water), by cross cells. Attached to the piles a timber roadway is constructed, with a line of railway for conveyance of the materials to the ends of the piers in course of construction.

The theory of this system of breakwater is—

First. That being to a certain degree elastic, the shocks from waves produce less injury than on a divided mass (as blocks for instance) perfectly rigid.

Secondly. That in a short time the internal interstices will be completely closed with sand; while the exposed surfaces will be coated, and so to speak agglomerated, with sea shells, weed, &c., so as to form eventually a solid mass, and at the same time protect the interior work from decay and the attacks of worms.

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[1] December 3rd, 1874. The Dutch Minister has this day introduced a bill into the Chamber, proposing to lengthen the south pier 492 yards, and asking a credit of 756,000 florins (£63,000), being at the rate of £128 per lineal yard. Sand has accumulated round the ends of the moles, the deep-water line seeming to recede from the shore as the moles advance into the sea. At present the depth is not 6 feet 7 inches at the end of the south mole at low water, where formerly it was 16 feet 5 inches.

The cost of the south pier was £145,000—about £38 9*s.* per lineal foot—a moderate expense for a pier averaging from 13 feet to 16 feet 6 inches high, where the cost of rubble stone is from 7*s.* 8*d.* to 9*s.* 2*d.* per cubic yard.

The objections to this system are that the progress must necessarily be slow, as the zinkstukken can only be sunk at rare intervals of calm weather. Nor is the problem yet definitely solved as to the durability of the fascines and timber-work.

The works have been carried out under the direction of Mr. M. P. Caland, Engineer-in-Chief and Inspector of the 'Waterstaat' or Dutch 'Genie Civile.' The Resident Engineer is Mr. M. J. Kluit.

A more detailed account of this great national work will be found in the report of Major-General Barnard, of the United States Army, on "The North Sea Canal of Holland; and on the Improvement of Navigation from Rotterdam to the Sea;"[1] and in the "Notice sur les Travaux Publiques en Hollande, par M. P. Croizette Desnoyers, Ingénieur-en-Chef des Ponts et Chaussées, 1874;"[2] from both of which treatises part of the information contained in this Paper has been derived.

The following extracts from the schedule of prices of the specification of the piers of the 'Hoek van Holland,' show the relative cost of each description of work :—

	£.	s.	d.
1 cubic mètre zink or grondstuk (without stone), sunk in place	0	7	8
1 „ „ fascines 'rysbeslag,' placed above low water	0	6	11
1 square mètre fascines, with tuinen	0	1	3½
1 mètre run of 'tuin'	0	0	5½
1 last (2 tons English) Tournay or other stone, sunk	0	11	10½
1 cubic mètre oak, rough (35 cubic feet English)	5	14	7
1 „ „ „ sawn to measure	8	10	3
1 „ „ red pine timber	5	19	3
1 „ „ white pine, or fir	4	5	10
1 lineal mètre oak piles, 3 to 6 mètres long, 0·60 to 0·80 mètre circumference	0	6	11
1 lineal mètre oak, 18 to 25 square, 3 to 5 mètres long, driven	0	7	8
1 „ „ „ 5 to 10 mètres long, 0·25 to 0·30 mètre square, driven	0	11	1
100 oak stakes 1·2 mètre long, driven	2	14	6
1 kilogramme forged iron, in place	0	0	7½
1 „ cast „ „	0	0	4½
1 day labourer, fascine worker, or pavior	0	2	1
1 day cart, with two horses and driver	0	7	8

The communication is illustrated by sketches and drawings from which Plates 11 and 12 have been produced.

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[1] *Vide* "Professional Papers of the Corps of Engineers, U. S. Army," No. 22. 4to. Washington, 1872.

[2] 4to. Paris, 1874.

APPENDIX.

On the Construction of the Sea Jetties for the Improvement of the Navigation from Rotterdam to the Sea. (Plate 12.)

The jetties consist of fascines, ballasted with stone and fixed by piles of oak.

The top width of the jetty is 29 feet 6 inches. The height of the stone pavement, taken at the centre, is 3 feet 11 inches above low water. The pavement is set in an arc of a circle, the concave side downward, with a chord of 29 feet 6 inches and a versed sine of 1 foot 8 inches. The fascines are laid in slopes of 1 to 1 at the south side, and of 1 to 1¼ at the north side. The second course of mattrasses (reckoned from the base) projects on both sides, thus forming berms each 16 feet 5 inches wide. The first course projects 19 feet 8 inches on both sides. The slopes of the fascine-work at the head of the pier are 1 in 8; the first course of mattrasses projecting 82 feet and the second 49 feet 2 inches from the jetty.

The mattrasses, which compose the body of the jetty, project northward 6 feet 7 inches, and southward 3 feet 3 inches more than is required by the original section, to afford level spaces whereupon to place the stones to protect the pier.

The thickness of a mattrass varies from 1 foot 4 inches to 1 foot 8 inches, and the filling-in at the axis of the work is 4 inches thicker than at the sides, to make up for the greater compression, occasioned by the increased weight acting on the mattrass. Generally the breadth of the mattrasses does not exceed 82 feet, otherwise the transportation, sinking, and ballasting would offer great difficulties. Their length is unlimited, but as high speed is required in ballasting mattrasses sunk at sea, extreme length would be unadvisable. The largest piece sunk at these jetties was 164 feet long and 91 feet 10 inches broad, being a superficial area of 1,674 square yards. For the dam across the river "Het Scheur," forming part of the works for the improvement of the navigation from Rotterdam to the sea, several mattrasses of about 2,392 square yards have been sunk.

The courses of mattrasses must overlap in such way that the joints of the under course are covered by the upper course.

The mattrass is made on shore, near the jetty, between high and low water, and when constructed, is floated to its destination, and fastened by anchors and ropes. Then the ballast stones, weighing, on an average, 120 lbs. each, are deposited on it from small vessels surrounding the mattrass, first over the middle, and afterwards over the general surface, till the mattrass is immersed. The sinking lines with which the vessels are attached to the mattrass are thereupon paid out, and at last detached; and in the meantime still more ballast is cast on the mattrass. Generally about 5 cwt. 1 qr. of stone per cubic yard will suffice to bring it aground, but at the north jetty 10 cwt. 2 qrs. of stone are charged per cubic yard of mattrass to oppose greater security against the shock of the waves.

When the fascine-work of the jetty is raised above low water, oak piles are driven through into the bottom in rows reaching 6 feet 7 inches above the water line. Rows of piles are also driven through all the layers under the track of the rails, laid for the conveyance of stone and other material. Elsewhere the rows of piles are shorter, and only serve to secure the stone revetment.

Between the rows of piles around the jetty forming the fore berm, and outside this berm, stones weighing, on an average, nearly 10 cwt. each are placed. Above low-water level the jetty is formed of osier layers 10 inches thick, secured by hurdles nearly 2 feet apart. The space between these hurdles is filled up to their top with rubbish or waste stone; the entire top of the jetty must be covered with stones weighing, on an average, 1 cwt. each.

In order to get well-connected joints, stones of a more regular form are

employed for this pavement. Experience has proved the stability of this mode of construction, heavy storms and strong currents not being able to damage the jetties.

When the bottom, along the head and the sides, is deepened, those parts of the mattrasses protruding from the jetties will, by their flexibility, follow the inequalities of the bottom and shelter the works from undermining.

On a movable bottom the foregoing method of construction offers guarantees of solidity which recommend its adoption wherever want of fascines or stone does not prove an objection.

According to the specifications for the jetties, the following prices are paid:—

	Dutch florins.
For 1 cubic mètre of mattrass (without the ballast) . .	4·50
For 1,000 kilogrammes of ballast stone	7·00
For 1 day's wages of a journeyman	1·20

No. 1,383.—"On the Separate System of Sewering the District of Tottenham, Middlesex, in 1851–2." By JAMES PILBROW, M. Inst. C.E.

THIS district was one of the first places operated upon under the Public Health Act of 1848. A local Board of Health having been formed, the Author was appointed engineer and surveyor to the Board, and the survey of the district was ordered. This was completed, with plans and estimates for carrying on the works, by the 1st of October, 1850; but the plans were not sanctioned by the General Board of Health till the 22nd of August, 1851. In the interval a drainage scheme for the town of Croydon had been approved.

In a report to the General Board of Health in October 1850, the Author stated:

"There are many large culverts, sewers, drains, and open water-courses at various parts of the parish, which, from their level, size and construction, are very unfit for real town sewage; it is proposed that ultimately all house drains shall be cut off from the same, and as they are sufficient for the general surface drainage, they shall remain to be used only for that purpose, without any or with few additions."

In a subsequent report to the Local Board on the 21st of November, 1850, he says:—

"I first examined the present sewers and public drains, nearly all of which I believe will be found marked upon the 'General Plan' by blue dotted lines, as also upon the sections. These I found to be of very irregular size, inclination, shape, and construction, and most of them far too large and faulty for the purposes of house drainage even if at a proper level, which they are not. Some of these sewers are not less than 4 feet wide by 5 feet high, with the crowns scarcely under the surface of the road; most of them are rectilineal in form, and contain from 6 inches to 1 foot of very offensive deposit. I consider that not one of these can be used for the purpose of house drainage. I recommend that the whole of the present sewers, after being properly cleansed,

should be used only for taking off the surface and storm waters, for which they are now mainly serviceable, and that every house drain, gully, or opening that conducts sulliage of any kind into them should be stopped. This done, I believe you will require little or nothing more for your surface drainage." (The length of these old brick sewers and drains was about 2½ miles.) And farther on—

"The works which I have the honour to recommend to your Board as necessary and effectual are an abundant and continuous supply of good water, laid on under pressure to every house which requires it throughout the town.

"That the 'Moselle' and all other open watercourses, as well as the present sewers and drains, should be cleansed after all house drains and sulliage are cut off from the same, and that they should then be used only as channels and drains for surface and storm waters, and that the 'Moselle' should be restored to its original course by lowering and enlarging the culvert at 'Scotland Green' and improving its level and banks through the 'Hale.'

"To thoroughly drain and sewer the town, &c., by well-laid stoneware tubular drains and sewers at proper levels, with the best inclinations that are possible, and to exclude therefrom all surface water and land springs. To conduct the whole of the sewage by a main sewer to one outfall, and that at the lowest convenient level, situated at the same time in such a locality as should render it easy to transmit the sewage by railway or water carriage, if any system of preparing and deodorising should be used, or, as an alternative, if it cannot be disposed of in any other way, that the outlet to the river be the best obtainable.

"To dispose of the sewage for the purposes of agriculture, if possible, and so as to be a source of revenue to the ratepayers, and thus lessen the rates. The converting privies into water-closets, by abolishing all cesspools, and adding pans, traps, and water pipes, which will render a copious supply of water very generally and absolutely necessary; and, therefore, I have looked around and closely considered the water supply."

These quotations explain a state of things which preceded the carrying out for the first time of the separation of the house sewage from the surface water and drainage.

In October 1851 the works for the drainage of Tottenham were completed under several distinct contracts.

The first, for glazed stoneware pipes, was taken by Mr. T.

Smith, of the Lambeth Potteries, at the following schedule of prices:—

STRAIGHT PIPES.

Internal Diameter of Pipe.	Length of Pipe in work.	Thickness of Material.	Price per Pipe.	
inches.	feet.	inch.	s.	d.
6	2	½		9½
7½	2	½	1	1
9	2	9/16	1	4½
12	2½	⅝	2	9½
15	2½	11/16	4	6
18	2½	¾	6	1½

These prices were exceeded—for curved pipes or bends by from 40 to 100 per cent., for single junction pipes by from 30 to 80 per cent., and for double junction pipes by from 50 to 100 per cent.

The pipes were made according to the design of the Author. The difference from the ordinary pipes consisted chiefly in lessening the shoulder of the socket by 'coning' it. By this means the shoulder did not exceed the thickness at the spigot end of the pipe, so that it was impossible for the edge of the shoulder of the socket to project upwards, as in the case of careless laying of pipes of the usual description, and thus cause an impediment which might eventually entail a complete obstruction to the flow of the sewage. The shoulder frequently becomes 'burred' through the manufacturer's practice of piling the pipes one upon another in the kiln, which often aggravates this evil. No doubt stoppages usually originated in this manner, but with the altered form stoppages in pipe sewers are unknown.

It was said that the bed of cement or clay placed under the spigot end of the pipe in forming the joint would always insure the level and flush position of the pipes; but experience showed that, allowing the joint to be made ever so tight with cement or clay, no sooner was the pipe laid than the men ran over it, or the earth was thrown in, the 'punner' set to work, and down went the end of the internal pipe, squeezing out the cement from the bottom, causing the mischief spoken of, and generally leaving an opening at the upper side.

In 1854 Sir J. W. Bazalgette, C.B., M. Inst. C.E., reported most favourably on the adoption of this principle and form of pipe

at Tottenham: "The pipes are circular stoneware socket pipes, formed with a bell mouth, so as to prevent the shoulder of one pipe projecting beyond the adjoining pipe in case of any settlement of the ground; and this appears to me a decided improvement on the usual form. The joints are made with Portland cement, and Mr. Pilbrow attaches great importance to this mode of jointing, because Portland cement, taking a long time to set, to some extent adapts itself to any settlement of the pipes which may happen while the ground is soft."

The pipes at Tottenham were carefully laid, and jointed with Portland cement in preference to Roman cement, which was at that time in favour with builders. The Portland cement was adopted on account of its taking longer to set, thus giving sufficient time for the settlement of the pipes and earth. Roman cement often sets before the man is clear of the pipe, and the joint is broken, permitting the sewage to escape into the soil; but Portland cement yields sufficiently, without injury, for a considerable period. The pipe-laying was done under a contract by a London sewer contractor, who found all labour and material, pipes and junctions alone excepted, which were furnished under the before-mentioned contract by the Board. The schedule of prices is given in Appendix A.

The contractor entered into an agreement to keep the whole in repair and good order for five years for the additional sum of £350.

The clause of the specification for laying the pipes was as follows:—"Each sewer or drain pipe must be placed in the trench singly and then driven home and jointed in the following manner, viz.: at the least one complete lap of tarred yarn shall be forced to the bottom of each joint, and as much pure cement applied, properly mixed with clean water, as may be necessary to fill up the remainder of the vacuity and to form a fillet or listing round the entering pipe, as shown by the drawings; and when gravel is the soil in which the trench occurs, the contractor shall puddle with clay immediately around each joint; and the contractor shall, without extra charge, execute all the required work and fix all bends, branches, and junctions which the engineer may direct to be inserted during the progress of the works; and shall place a plain tile against every eye, or branch, or junction opening before filling in, temporarily to keep the earth out till the house drains are completed and made to the same, and make good any defects that may occur therein within the time before mentioned."

And for excavating the trenches—

"The contractor shall excavate the whole of the trenches which

may from time to time be required, and he shall, before proceeding to dig out the subsoil, carefully take up and lay aside, so as not to become intermixed with other materials, all the turf, vegetable mould, pebble, pitching, metalling, or other crust forming the surface of any of the fields, gardens, grounds, roads, footways, or pavements along which the pipes are intended to be laid. He shall then excavate the ground for the sewerage to the depths shown by the sections, and shall, in addition, form all proper and necessary joint-holes. And for the water pipes (unless with special leave or order to the contrary) excavate or form a 'benching,' or 'shelf,' or side cutting in and in addition to the said trench for sewage pipes, as described or shown by the drawings, to not less than 2 feet 6 inches in depth below the surface of such streets, highways, and places."

By this method the cost of laying the water pipes was but two-thirds of what the contractor charged for laying them by a separate trench. The subsequent mode of proceeding was to fill in the trench to within 6 feet or 7 feet of the surface, and then to form the benching. The jointing of the iron pipe was thus better, because more conveniently, made, as the workman now stood in the trench at his work hand high.

Before one-third of this contract was completed the contractor absented himself from the work, leaving the men unpaid; whereupon the Board took possession of the plant, &c., and the work was finished under the superintendence of the Author, at a cost, little, if at all, exceeding the sum which the contractor would have received, and with far better workmanship.

Man-holes, or inspection shafts, were constructed at special places and at the junctions of the principal branch sewers; they were of ordinary brickwork in cement, covered with a York landing. Ventilating shafts, or outlets, were also inserted at such places as the rain-water pipes of the tower and turrets of the churches or of lofty buildings; in the interior of garden walls when the sewers passed through open grounds, or by metal pipes up trees. They were not much needed with a free outlet, but would be best superseded by other means of ventilation.

At the head of branch or lateral sewers (especially in courts and alleys) 'flushing shafts' were placed. These were not intended solely for flushing or cleansing the sewers, but as much for purposes of examination. The shafts were provided with a cast-iron head fitted with a wooden plug, which was sometimes replaced by a plain York stone 18 inches square, or by a cast-iron cover or box. Near these a fire-cock or hydrant was always erected, so that

when the branch sewer required flushing or testing, a short length of canvas hose was attached to the hydrant, and the other end being inserted into the flushing shaft, the water when turned on rushed along the sewer, and, if the latter were clear of impediments, flowed into the main sewer. This was ascertained by opening one of the inspection shafts near the junction of the branch sewer with the main. It was premised that if a stoppage had taken place, the water would rise up the flushing shaft, and generally, by the increased pressure, urge forward the obstructing substance and remedy the evil; or, if not, would indicate the locality within a few yards, by causing the water to show itself in the house drains above the place of stoppage. Fortunately, there was no experience of this sort, and the shafts went gradually out of use.

In many instances the shaft hose and the hydrant were superseded by a 1½-inch iron pipe, with a stop-cock, carried from the nearest water pipe to the head of the branch sewer. By the occasional use of these contrivances the inspector was not only enabled to satisfy himself as to the action of the sewers, but it could be proved whether a stoppage was occasioned by obstacles in a house, or private drain, or in the public sewer. In a system of pipe sewers this is of great advantage, and will often save expense and trouble. But neither during the first seven years of the working of this system, for which time the Author had the supervision of it, nor since, a period altogether of twenty-three years, has there been a case of stoppage of these pipe sewers.

The length of the main sewer leading from the upper end of the town rather exceeded 2 miles, with a fall of only 20 feet to the surface of the River Lee in the mill tail below the Tottenham Lock. This would give a uniform inclination of about 1 in 544; but as it was not possible to preserve uniformity, on account of the variation of the surface-level of the ground, the sewer was arranged as follows:—

	Feet.	Fall.	Diameter of sewer pipe. Inches.
The first	62	1 in 80	7½
The next	247	1 in 150	7½
"	1,200	1 in 340	9
"	1,000	1 in 340	12
"	315	1 in 635	12
"	1,495	1 in 635	15
"	1,913	1 in 659	18
"	1,655	1 in 826	18
"	3,000	1 in 1,062	18

The only alteration which the General Board required was in the size of the lower 3,000 feet of the sewer, which was diminished from 21 inches to 18 inches in diameter. This sewer, on the separate system, has efficiently drained for twenty-three years an increasing number of houses. They now number three thousand at least, the sewage and water from which find their way to this sewer alone. Additional pipe sewers have been laid during the last twelve years for newly-built and outlying districts containing nearly three thousand fresh houses.

The whole of the sewage of about eight hundred houses has passed through the 12-inch pipe forming the upper portion of this main sewer ever since it was first laid down.

The practice of the Author, as far as the unusual flatness of the district and levels would permit, was to diminish the fall of the sewers in their course from the summit to the outlet and as they increased in their dimensions; a practice that has proved very successful and satisfactory.

This sewer, with its lateral branches, drained about two thousand houses by the time the original works, including what were termed the 'private improvements,' were completed. The quantity of sewage discharged per diem in 1854, with certain land water which gained admission into portions of the sewer, was about 200,000 gallons.

From examinations at various localities in the course of the sewer the following facts were elicited. That articles put in at the upper end, such as corks, turnips, &c., were discharged at the outfall in from forty-five to fifty-five minutes, being at the average rate of about 2½ miles per hour. Beginning the journey slowly, the sewage increased its speed; the lateral branch sewers discharging their contents raised the surface-level, till the maximum velocity was attained, where the 15-inch pipe was succeeded by the 18-inch pipe; it there spread over the larger invert, and, coming on to a much less effective inclination for some distance, declined in speed. The stream had sufficient force to carry down stones and pieces of brick of large size. On approaching the outlet the velocity again became greater. About midway, that is in the 15-inch pipes, the sewage reached a depth of 7 inches, occupying nearly one-half the sectional area of the sewer. At about ½ mile from the outfall, in the 18-inch sewer, it was 5¾ inches deep, and at the outlet itself only 2¾ inches deep.

The maximum flow of sewage was between the hours of 9 A.M. and 11 A.M., except on Sundays and Tuesdays. On Sundays it was from 10 A.M. to 0.30 P.M., and on Tuesdays from 8 A.M. to noon. On

each day the minimum was before breakfast, except on Tuesdays and late in the evening. Most water was consumed on Tuesdays and Saturdays, the latter day showing a greater quantity for the evening than any other, and Sunday the least aggregate of any, though on the forenoon of that day, in summer, the consumption was often equal to that of some of the week days.

Considering that the new system excluded all surface drains and unprotected drain heads, and only afforded slight means of ingress to the sewers through small drain pipes and traps belonging to water-closets and sinks, which never exceed 3 inches and 4 inches in diameter, it was surprising to find such a variety of materials carried down to the outfall tank. Pieces of soap were among the most plentiful and valuable perquisites to the man employed at the outlet; the next most abundant products were scrubbing brushes, hearthstones, every kind of rag clout, flannel, pieces of linen and cotton cloth, and even small tinware, crockery, and glass were not uncommon.

The mouth of the sewer was kept free, and was not allowed to be submerged or 'water-logged' by the sewage or water in the stream or tank. This is a point on which much depends, not only as regards the efficient flow of the sewage itself, but also as regards the ventilation or accumulation of gases in the sewer and its branches. For instance, if the outlet be quite submerged, gases evolved from the sewage accumulate in the upper and unoccupied portion of the sewer, and, gaining pressure by degrees, find their way into the house through the 'water traps,' unless there be means, by 'ventilating shafts,' for an easier passage of escape. Although, as a precaution, such ventilators were made, experiments seemed to prove they were not so much required for this purpose as was generally supposed. It was found that in a close and perfect pipe sewer, such as that at Tottenham, having few openings directly to the atmosphere, the surface of the stream of sewage water, acting by friction upon the air or gas which occupied the upper part, carried the latter along with it. So powerful was this effect, that, on making a small opening near the top of the pipe, there was an indraught of air, in place of an escape of gas, sufficiently strong to draw the flame of a candle into the hole, and, in one instance, nearly to extinguish it.

Further observations pointed to another important reason for having a tolerable depth, or sectional area, of the sewage water as well as velocity, for it was found that, if the stream was very shallow, the solids were left 'stranded' at the margin of the stream or at the bottom of the pipes, and nothing but violent

flushing would afterwards remove them. The most effectual and economical method, then, is to have depth enough to float all solids that will float, and velocity enough to propel semi-floating matter when lightened by immersion.

The Author early learned that a pipe or other smooth and well-laid sewer could have too great a fall, thereby attenuating the stream by its velocity, and leaving the more sluggish-moving and ponderous solids high and dry. In the town of Bridgenorth, where the levels vary so much as to place the basements of the houses in one street above the roofs of those of an adjoining street, to check the velocity of flow, the sewers were made in 'steps,' being laid for the necessary distance at the approved inclination, then dropped almost vertically, and continued for another length as before.

With respect to the question of ventilation, it was thought objectionable to bring shafts up to the surface of the roads and paths, because if noxious or unpleasant effluvia escaped therefrom, passengers and shopkeepers would be annoyed. If the flow of sewage be moderately active, and the outlet of the sewer free, little or no gas will pass up the drains to the houses. The chief source of the noxious odours rising into houses is their own drains and traps, and the only effective remedy appears to the Author to be by ventilating the house drain instead of the sewer, which, nevertheless, is by this means greatly benefited. The best method of accomplishing this is believed to be by constructing the water-closets, where there are more than one, above each other, and having a 4-inch vertical pipe extending from the basement to above the ridge of the roof, and open at the top. Into this vertical pipe every water-closet should empty itself by a 'siphon' water-trap. This plan has never failed, and it is evident that if all house drains were thus dealt with, further ventilation of the sewer would be unnecessary, for, should any gases pass from it towards the house, they would escape up this pipe rather than through the water of the traps. To keep the house entirely free from unpleasantness and danger, it would only be necessary to use plenty of water, which would prevent anything offensive remaining in the water of the trap itself. When it is desired that this pipe should act as a ventilator to the sewer, the trap must not be inserted. Except in cases of new houses or extensive alterations the foregoing method could not be carried out, and, therefore, recourse was often had to the alternative of substituting a small zinc pipe as a ventilator from the upper trap, if more than one, or the 4-inch pipe. At the period of the Tottenham works 'charcoal

filter pans' for sewer ventilation were unknown; but when the Author executed the drainage of the city of Canterbury in 1868 they were much in use; yet it was feared that they tended to impede the passage of gases from the sewers, and the old means of 'stack' pipes, soil pipes, and shafts carried up church towers and to steam-boiler chimney shafts were preferred and adopted with satisfactory results.

The same pattern of pipe was used at Canterbury as that first employed at Tottenham and in towns subsequently drained by the Author; and also as nearly as could be the same principles were carried out as to moderate inclination, increasing the rate of fall as the sewer receded from the outfall, and allowing some land springs ingress; these being under certain conditions a great assistance to the working of the sewer. The outfall sewer at Canterbury had also a nearly similar inclination (1 in 1,090), though it was larger and oval in section, 3 feet by 2 feet, and composed of brick in cement; the lower half was also rendered with cement. For the sake of comparing the prices at Canterbury in 1868 and those at Tottenham in 1851, the contractor's schedules of prices for pipes and pipe-laying are given in Appendices B and C. It should be mentioned, however, that in the contract for laying the pipes at Canterbury, the contractors, Messrs. Dickenson and Oliver, of London, were egregiously out in their prices for the greater depths, although they honourably fulfilled their contract, and, in so doing, lost a considerable sum of money.

Reverting again to Tottenham, one, if not the greatest, difficulty met with in the earlier experience of house drainage was from the accumulation of grease in the scullery sinks. As these pipes were closed against rats, they could not clear off the grease as they were wont to do in the old brick drains.

According to the dictates of the General Board at the time, house drains were to consist of 4-inch and 3-inch pipes, and even 2½-inch pipes were spoken of; the 4-inch pipes were for draining water-closets, and the 3-inch pipes for sinks. These sizes were adopted at Tottenham. The 3-inch pipes for the kitchen sinks gave at one time the greatest trouble and annoyance, and they were generally superseded within six or twelve months after completion. This was particularly the case when the sink lay far from the other parts of the house which required drains, and where the pipe, as in some instances, had to be carried half round the house. The mischief showed itself by the accumulation of grease until the pipe was choked. In one instance the 3-inch pipes were taken up at a private house, and found to be quite filled with

grease for many yards. A length of 18 feet of pipe was laid upon the lawn, and when broken a column of grease was exposed to view. This was solid, excepting a small hole down the centre, not more than ¼ inch in diameter. The section of the grease showed that it had been deposited in concentric rings, caused by the grease contained in the hot water thrown down the sink cooling as it passed along, and adhering all round the pipe, so that in course of time only a small passage was left. Boiling water poured down the sink pipe to melt the grease and carry it off only increased the evil, by conveying it further away to be cooled and deposited. The only certain and efficient plan of preventing the grease nuisance, and another more injurious to health, namely the effluvium rising into houses caused by the bell-trap of the sink being removed, is to arrange that the sink pipe shall pass through an outer wall and discharge over an exposed drain grating, in itself well trapped. This course was subsequently adopted wherever it could be.

Hitherto the public or general works have principally been referred to, viz., those which are paid for by a general rate; but an important part of the proper drainage of a town requires serious consideration and a collective outlay, when, as in the case of Tottenham before the new system of sewers was in operation, there were no proper house drains, water-closets, or water supply. Thus, in Tottenham, more than in most places, the houses, with very few exceptions, had water laid on, the drainage completely re-arranged, and cesspools filled up. This work, termed 'private improvements,' was not commenced until the public works were completed.

Contracts were entered into, upon a schedule of prices, for all the various descriptions of work likely to be required, the Board providing the principal materials, *i.e.*, stoneware pipes, pans, &c. Where a better class of material or workmanship was desired, private arrangements were made between the contractors and the owners or occupiers of houses. A schedule of the prices adopted in Tottenham in 1852 is given in Appendix D. The particulars of altering and completing the drainage of six cottages, executed by the Board, as a sample or model, both as regarded the method and necessary cost, will be found in Appendix E. The average cost of these 'private improvements' to the usual class of houses in Tottenham was £8 per house; but there were many instances where work was done to the amount of £20 to £40, and in a few cases much more was expended.

The surplus earth from the trenches was used to fill up the

many stagnant ponds and ditches which, when the drainage was done, and water mains laid throughout the district, were rendered of no further use either in cases of fire or for other purposes. By so doing a great source of malaria was removed. A certain quantity of the surplus soil was put on one side for filling up the cesspools when common privies had to be converted into water-closets. This latter operation was performed under the contract (mixing one-tenth part of quicklime with the earth), as also was the preparatory emptying of the cesspits.

Tottenham was by no means a favourable place for the introduction of a new scheme of drainage, the inhabited part lying low and flat, on the margin of the marshes and of the valley of the Lea. The water of the navigable portions of the river and the new 'Cuts,' called the Lea Navigation, was penned up by locks, so that the surface was above the marshes and the level of the ditches and watercourses. The only means, therefore, of obtaining a locality for an efficient outfall, without pumping, was to carry the outlet of the main sewer below the lower lock. The parish was a straggling one, necessitating a disproportionate quantity of work. The main sewer was laid principally through a stratum of shingly gravel beneath the alluvial soil of the marshes which fringe the valley of the Lea. This gravel contained much water from the numerous land springs; other portions of the district consisted of brick loam and London clay.

The original drainage completed, as above described, in 1851–2, consisted of 8¾ miles of pipe sewers of all sizes, and was effected within the engineer's estimate of £3,672 14*s*. 8*d*.[1]

Had the Tottenham drainage been carried out on the 'mixed' in place of the 'separate system,' the cost would have been at least seven times as much; for the old sewers, extending to a length of 2½ miles, would not have been available, being too shallow for house drains.

There was no economy in the adoption of pipes in preference to brick sewers over a diameter of 15 inches, when a single brick ring would suffice; but in cases such as that of the 'outlet' at the Canterbury sewage works, leading from the filters across

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[1] The cost of the combined works of water supply and drainage was £7,500; the number of houses benefited was 1,555; the rateable value of the property in 1852 was £25,596 15*s*. The money was borrowed at 4½ per cent. per annum, and the cost of the works was spread over a period of thirty years, giving a special district rate of 4½*d*. in the pound, or an average cost of 1·23*d*. per house per week. The total length of water-mains and branches laid down was 10 miles. The water rate, which was 2½*d*. in the pound, has since been much increased.—J. P.

the marshes to a point in the river Stour below the 'town' of Fordwich, to convey the supernatant water to the river, where the external water had to be excluded, pipes were not only the cheapest, but almost a necessity, as the whole of the work had to be executed below the surface-level of the river and water-courses, often through gravelly or boggy soil, and where the springs were so strong as to wash the cement out of the joints of brickwork as fast as it was laid.

It was found necessary to devise some efficient kind of water-closet for factories, common public schools, &c., about which there should be nothing that the users could destroy, impede, or waste, and such an arrangement was designed by the Author, which will be sufficiently explained by Figs. 1 and 2. It was adopted at several places, and a person was employed at certain times of the day to let the water on and discharge the contents.

Although little was then known about the treatment and disposal of sewage, irrigation and other methods were considered and discussed. Irrigation of the marshes was impracticable, on account of 'Lammas rights,' and of their being subdivided into numerous small holdings, as well as being water-logged through the greater part of the year. A scheme of build-

Fig. 2.

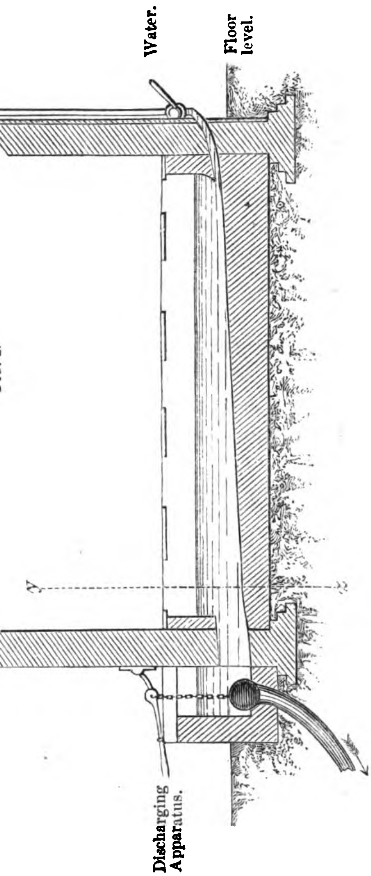
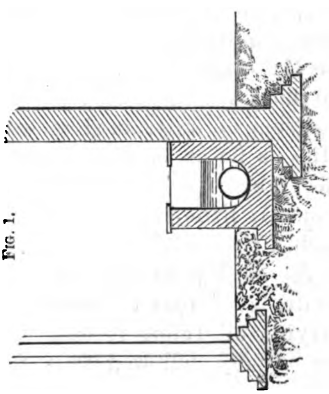


Fig. 1.



Section at y z.

ing a set of barges for the purpose of carrying the sewage to distant places was considered, but not attempted. Finally, Mr. Higgs, whose mode of treating sewage was in operation at Leicester under the management of the late Mr. Wicksteed, M. Inst. C.E., came forward, took the sewage on a lease of twenty-one years, and erected works of a very complete nature, at a cost of £10,000. These were executed with the professional assistance of the late Mr. C. May, M. Inst. C.E., the Local Board providing the land and site for the works. Mr. Higgs's process was precipitation by lime, and desiccation of the products, for which latter purpose expensive machinery was erected. A portion of the product was formed into 'bricks,' and the rest packed into bags in a state of fine powder, called 'Tottenham guano,' and sold, it was said, satisfactorily for a time; but Mr. Higgs dying a few years after, the Board received so many complaints, added to their own experience in the matter, that upon more serious action being taken by the Trustees of the River Lea, the works were abandoned.

The Author's experience leads him to conclude that the separate system of sewering a town will ultimately have much to do with the success of sewage treatment and disposal. It must always be easier to treat a limited and uniform flow of sewage, and, therefore, exclusion of rain is of the greatest advantage. This may be instanced by the case of Watford, of which the principal part was drained about the same time as Tottenham, in 1852; but the sewers were chiefly of brickwork and of large size, as they received the water from the surface of the roads and streets. The town being on a considerable ascent, the sewers had a rapid fall, and the storm water running along equally-inclined surface channels, carried much débris with it, overcharged the gully pits and traps, and filled the sewers, which discharged a torrent into the tanks at the outfall. In dry periods the reverse was the case: if rain did not occur for several weeks the soil from the houses accumulated in the larger sewer; for although the modicum of water used at each house might carry the soil and solids as far as the main sewer, so small a quantity had but little effect when spread over the invert of a larger channel, and consequently little beyond a very small stream of nearly clear water reached the outfall for days or weeks together. Then came a storm, or thoroughly wet day, and the accumulation of sewage, with hundreds of tons of water, rushed into and flooded the tanks, carrying all before it over the filter beds into the river. This was usually followed in a few days by complaints from mill-

owners, and the frequent recurrence of such events soon led to legal proceedings. Such was the state of things at the time when the Author was constructing waterworks for the Local Board, and sewage tanks and filters for the Local Board and the Earl of Essex conjointly. Had the surface water only been removed by superficial drains, it might have been carried into the river at a comparatively small outlay, and the house soil, by a system of moderate-sized pipes, could have been conveyed to the outfall works, which would, in that case, have been much smaller and less costly.

It is evident that if the rainfall is excluded from the sewers they will be useless without a copious house supply of water, and their dimensions must not be larger than is sufficient for their duty under these circumstances. It is therefore necessary, before completing a drainage scheme, to consider the water supply, which must be abundant in quantity, laid on to every dwelling under pressure, and be 'constantly on.'

At Tottenham, when the drainage scheme was proposed, there were no waterworks, beyond wells and pumps for the larger houses, and three or four public pumps and 'Artesian fountains,' with ponds and watercourses, or land spring wells, for the smaller ones. Deep wells were generally too expensive, so that the Local Board, by the advice of the Author, took the question of water supply into consideration at the outset. Waterworks, on a very economical plan, were first constructed; for it was believed by the Board that few persons would voluntarily have the water laid on. So strong was this conviction, that when it was proposed to arrange the works for a supply to fifteen hundred houses only, it was argued that three hundred would never be found to take the water. However, instructions were given for meeting the demand of seven hundred houses, and ultimately works were constructed equal to about one thousand houses. But by the time the 'house connections' with the sewers were completed, no less than fifteen hundred and fifty houses had to be actually supplied, or the occupiers had applied for water to be laid on. In 1851 it was considered that only fifteen hundred and fifty houses existed within the drainage area to be connected with the sewers, the population of the district at that time being ten thousand. In 1853 they had increased by nearly one thousand, so that the Author had to enlarge the waterworks twice in the first six years, under great opposition from the ratepayers and others, till their original power and means of distribution were increased more than five times. It soon occurred to the Author that a difficulty would arise from the 'high pressure' of the water and its 'constant service,'

namely, the waste, either wantonly or accidentally. To remedy this the Author invented a simple apparatus, which was brought out by Messrs. Guest and Chrimes, of Rotherham, termed a 'water-waste preventer,' which answered well as long as it was used in towns where the inventor had control, but it was probably little known beyond. This instrument, which was sold at 18*s.*, allowed one (or two, if so arranged) pailfuls of water to be drawn by once opening the tap. If more water was required, the tap had to be closed for half a minute, and then another pailful could be filled, and so on. A very moderate consumption of water was consequently brought about in Tottenham during the Author's connection with that place. In 1855 and 1856 the average consumption, including all kinds, was only 63½ gallons per house per diem; while at that time a town on the south of London was complaining of a consumption of water of between 200 and 300 gallons.

The conclusions to be drawn from the Author's experience would seem to be—

That the 'separate system' of draining a town is the best, if not an absolutely essential condition, when the sewage has to be collected, treated, and disposed of otherwise than by discharging it into a river or the sea, or, when first cost is a consideration, and some surface drainage already exists: that a moderate inclination is often better than a great one: that ventilation may be most effectually secured at the houses: that spring water may often be advantageously allowed ingress to a sewer when the soil is permanently saturated; but should this not be the case the opening, which at one time would admit water, would at another let the sewage out: that flushing arrangements should be provided, if only as a convenient means of ascertaining the state of any particular sewer: that Portland cement, and not Roman cement, and never clay alone, should be used for the joints of sewer pipes: that a copious supply of water to the houses should be the first consideration: that scullery sink pipes should be detached from direct communication with the drain: and that it is desirable to avoid the ledge caused by careless laying of pipes, by having them 'coned' at the socket end.

APPENDICES.

Appendix A.—Schedule for Drain Pipes, Tottenham, 1851.

1.—If laid in Macadamized or Gravelled Roads or Streets.

Description of Pipe.		Price per Lineal Yard, measured in Work, including all Appendages.									
Diameter.	Length in Work.	Above 3 feet deep and not exceeding 4 feet.	Above 4 feet and not exceeding 5 feet.	Above 5 feet and not exceeding 6 feet.	Above 6 feet and not exceeding 7 feet.	Above 7 feet and not exceeding 8 feet.	Above 8 feet and not exceeding 9 feet.	Above 9 feet and not exceeding 10 feet.	Above 10 feet and not exceeding 11 feet.	Above 11 feet and not exceeding 12 feet.	Above 12 feet and not exceeding 13 feet.
Inches.	ft. ins.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
6	2 0	0 7½	0 8½	0 9½	0 10½	0 11½	1 0½	1 1	1 2	1 3	1 4
9	2 0	0 7½	0 9½	0 10½	1 0	1 1½	1 3	1 4½	1 6	1 7½	1 9
12	2 6	0 8½	0 10¾	1 0¼	1 4½	1 5¼	1 6¼	1 8¼	1 10¼	2 0¼	2 2¼
15	2 6	0 9½	1 0	1 2½	1 5½	1 7½	1 10	2 0½	2 3	2 5½	2 8
18	2 6	1 1½	1 4½	1 7½	1 10½	2 1½	2 4½	2 7½	2 10½	3 1½	3 4½

2.—If laid in Footpaths or Courtyards.

6	2 0	0 6	0 7½	0 8½	0 9	0 10½	0 11	1 0	1 1	1 2	1 3
9	2 0	0 6½	0 8¼	0 9½	0 11½	1 0½	1 2½	1 3½	1 5	1 6½	1 8
12	2 6	0 7¼	0 9¼	0 11¼	1 2¾	1 3¼	1 5¼	1 7¼	1 9¼	1 11¼	2 1¼
15	2 6	0 8½	0 11	1 1½	1 4	1 6½	1 9	1 11½	2 2	2 4½	2 7
18	2 6	1 0	1 3	1 6	1 9	2 0	2 3½	2 6	2 9	3 3½	3 5

3.—If laid in Gardens, Yards, or Open Fields.

6	2 0	0 2¾	0 3¾	0 4¾	0 5¾	0 6¾	0 7¾	0 8¾	0 9¾	0 10¾	0 11¾
9	2 0	0 3¼	0 4¾	0 6¾	0 7¾	0 9¼	0 10¾	1 0¼	1 1¾	1 3¼	1 4¾
12	2 6	0 4	0 6½	0 8	0 10	1 0	1 2	1 4	1 6	1 8	1 10
15	2 6	0 5¼	0 7¾	0 10¼	1 0¾	1 3¼	1 5¾	1 8¼	1 10¾	2 1¼	2 3¾
18	2 6	0 6½	0 8½	1 2½	1 7¾	1 8¾	1 9½	1 11½	2 4½	2 5½	2 10½

Appendix B.—Schedule for Straight Pipes, Canterbury, 1868.

Internal Diameter of Pipe.	Probable Number required.	Length of Pipe in Work.	Thickness of Material.[1]		Price per Pipe.	Rate of Delivery after Order.
Inches.		ft. ins.	inch.		s. d.	Per Week.
8	3,200	2 0	0·80	0·75 (8 and 9 in.)	1 4¾	1,000
9	13,300	2 0	0·90		1 6	2,000
12	9,900	2 0	1·10	1·0	2 6¾	2,000
15	1,800	2 6	1·25	1·10	5 7½	500
18	640	2 6	1·50	1·25	7 6	200
24	3,500	2 6	1·75	1·75	F.C. 12 6 D.C. 13 6	Three weeks' notice.

[1] The thickness of pipe was altered before the contract was taken to that shown by the small figures.

Note.—F.C. fire clay. D.C. Dorset clay.

APPENDIX C.

SCHEDULE for LAYING PIPES, CANTERBURY, 1868.

If laid in Macadamised or Gravelled Roads and Paved Streets.[1]

Description of Pipe.		Price per Lineal Yard, measured in Work, including all Appendages.						
Diameter.	Length in Work.	Above 3 feet deep and not exceeding 4 feet.	Above 4 feet and not exceeding 5 feet.	Above 5 feet and not exceeding 6 feet.	Above 6 feet and not exceeding 7 feet.	Above 7 feet and not exceeding 8 feet.	Above 8 feet and not exceeding 9 feet.	Above 9 feet and not exceeding 10 feet.
Inches.	ft. ins.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
8	2 0	1 8½	1 9½	1 9½	1 9½	1 9½	1 10½	1 11½
9	2 0	1 8½	1 9½	1 9½	1 9½	1 9½	1 10½	1 11½
12	2 0	1 9½	1 10½	1 11½	1 11½	1 11½	2 0½	2 1½
15	2 6	1 10½	1 11½	2 0½	2 0½	2 0½	2 1½	2 1½
18	2 6	2 0½	2 1½	2 2½	2 2½	2 3½	2 4½	2 5½
24	2 6	3 3½	3 4½	3 5½	3 5½	3 6½	3 7½	3 7½

Description of Pipe.		Price per Lineal Yard, measured in Work, including all Appendages.						
Diameter.	Length in Work.	Above 10 feet and not exceeding 11 feet.	Above 11 feet and not exceeding 12 feet.	Above 12 feet and not exceeding 13 feet.	Above 13 feet and not exceeding 14 feet.	Above 14 feet and not exceeding 15 feet.	Above 15 feet and not exceeding 16 feet.	Above 16 feet and not exceeding 17 feet.
Inches.	ft. ins.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
8	2 0	2 1½	2 2½	2 2½	2 3½	2 4½	2 5½	2 7½
9	2 0	2 1½	2 2½	2 3½	2 3½	2 5½	2 6½	2 7½
12	2 0	2 2½	2 3½	2 4½	2 5½	2 6½	2 7½	2 8½
15	2 6	2 2½	2 3½	2 5½	2 6½	2 7½	2 8½	2 9½
18	2 6	2 6½	2 7½	2 8½	2 9½	2 10½	3 0½	3 6½
24	2 6							

[1] N.B.—If laid in footpaths, or courtyards, gardens, yards, or open fields, these prices were ½d. less on each item.

APPENDIX D.

TO FIX OR LAY DOWN PIPES and APPENDAGES for DRAINAGE on the TUBULAR PIPE SYSTEM, and for SUPPLYING with WATER on the CONSTANT SYSTEM HOUSES with CONSTRUCTION to RECEIVE CLOSET, and for the SURFACE DRAINAGE and CLEANSING.

	s.	d.
Drainage—laying 6-inch pipes, per foot	0	7
" " 4-inch " "	0	5½
" " 3-inch " "	0	5
" " 2-inch " "	0	4½

	s.	d.
Bends and junctions . . . . (each)	0	3
Siphon traps	0	3
Yard sinks.	1	0
" " laid in brick	3	6
Plug box to stop-cock	5	6
Emptying and filling cesspools	7	6
Making good floors (brick)	1	0
" " (stone)	2	6
" " (boarding)	3	6
Providing W.C. 4′ × 4′ (the building as specified) . . .	90	0
" " 3′ × 3′ " " " . . .	80	0
Converting privy into W.C.	12	6
Removing "	50	0
Tapping main and junction of sewer	12	6

Water supply—

1-inch wrought-iron pipe, per foot	0	4½
¾-inch " " "	0	4
½-inch " " "	0	3
1½-inch and 2-inch cast-iron "	0	4
Ferrules or preventers	2	0
Extra for a coburg	1	0
Cock, up to ¾ inch	0	9
Large cocks—2-inch, 2/6; 1½-inch, 2/0; 1-inch, 1/6.		
Partial conversion.	2	6

APPENDIX E.

Actual Cost of Private Works for the Water Supply and Drainage of Six Cottages in Tottenham, the Property of Thomas Tilley (laid on from the Water Mains and to the Drainage Pipes of the Local Board of Health).

Works executed in August, 1852.

Water supply (all as fixed)—

	£.	s.	d.	Per Cottage. £.	s.	d.
95 lineal feet of ¾-inch galvanised wrought iron pipe, with bends, &c., 6 ferrules . .	4	9	3¼	0	14	10½
93 lineal feet of ½-inch and ditto, ditto, block tin pipe	3	10	2¼	0	11	8½
Two ¾-inch brass stop-cock on main branch	0	7	0	0	1	2
Six brass bib cock (screw-down) of ½-inch .	0	12	6	0	2	1
Two self-closing cocks	0	18	0	0	3	0
Four common lever stop-cocks, ¾-inch . .	0	15	2	0	2	6½
Six water-closet pans, with traps, &c . .	1	7	0	0	4	6
Four 'water-waste preventers'	3	12	0	0	12	0
Total for water supply	15	11	1½	2	11	10½

Drainage—

	£.	s.	d.	Per Cottage. £.	s.	d.
135 feet of stoneware pipes (each 2 feet long, of 4-inch, 3-inch, 2-inch diameter), including curves, junctions, and traps . . .	2	10	6	0	8	5
Laying and jointing the same at average depth of 4 feet, and making good to surface	4	9	9	0	14	11½
Emptying and filling up six old cesspools .	1	10	0	0	5	0
Bricklayer setting six water-closet pans, making good walls adjoining old cesspools	3	0	0	0	10	0
Six new yard sinks and traps	0	15	0	0	2	6
Total for drainage	12	5	3	2	0	10½
Total cost of both classes of private works	27	16	4½	4	12	9

NOTE.—Each cottage has a separate water-closet, also a separate water tap carried within doors.

No. 1,374.—"On the Driving of Piles to Resist the Force of Ice, tending to draw them from the ground." By JOHN WILLIAM JAMES, M. Inst. C.E.

IN Canada and the United States timber is extensively employed as a material of construction, and in many important as well as minor works supersedes masonry.

Notwithstanding the appearance of instability and roughness which public works on the continent of America usually present, and which contrasts unfavourably with the highly-finished structures in Great Britain, so much is being done, and remains to be done, in America in opening up new territory, and in providing for the increasing wants of the older States and Provinces, that expedition and economy in construction are of paramount importance. Timber piles, where abundant, suitable, and comparatively cheap, supply these requirements better than any other mode of construction; hence piles are found supporting important structures along public roads, railways, navigable rivers, and in harbours.

It is generally the care of the constructor to drive piles only so far that they shall be able to support a specified superincumbent weight, without penetrating the ground further; but in Canada and in the Northern States of America an element of destruction, which has no existence in temperate climates, has to be guarded against. During the severe winters those countries invariably experience, the ice attains a maximum thickness on the approach of spring. As the sun reaches a greater altitude, and the snow melts, the rivers become swollen, pressing the ice upwards. Under such circumstances, if piles inclosed by ice have not a sufficient hold in the ground to withstand the great pressure brought to bear on them, they must be lifted with the ice, and the wreck of the structure they support will be inevitable.

So far as the Author is aware, the resistance of a pile to the action of a specified force applied in drawing it from the ground has never been investigated. The question is apparently capable of solution, at least so far as to give the constructor some knowledge of the value of his work. It can at best be but approximate, for the adhesion

of ice to timber varies, within certain limits, with the temperature, and piles do not under all circumstances hold the ground with equal tenacity. In tidal harbours the ice is not at rest for a sufficient length of time to produce an effect of this kind on piles; but it is very different in the harbours on the great lakes, where thick ice is formed. A storm raises the level of the water in harbours on a lee shore, and as the ice in them may not have been subjected to disturbing influence for weeks, it adheres with great tenacity to the piles, especially when the temperature is low, and occasionally draws them from the ground. Rivers above tidal influence, unless confined by dams for the use of mills, are only affected by a rise of temperature, when the melting snow causes floods that lift the ice. When the temperature is below the freezing point, the adhesion of ice to timber is equal to its cohesion. This may be observed where the level of a body of water dammed back is subject to an occasional rise and fall; if a rise in the height of the water is caused by an increase of temperature, the ice becomes detached from the pile; but should a change take place in the level of the water when the temperature is below the freezing point, the ice generally breaks round the pile at a short distance, leaving a ring of ice adhering to it.

The force that can be exerted by ice on any one pile may be readily ascertained if the thickness of the ice and its adhesive power to timber are known. In the early part of the year 1873 the Author made eight experiments, which gave a mean result of 29·43 lbs. per square inch as the adhesion of ice to timber (page 201).

With regard to the driving of piles to enable them to resist a force tending to draw them from the ground, the elements available for calculation are —the weight of the ram, the space it falls through, and the space through which the pile is driven by the blow. Professor Rankine gives a formula for calculating the effective resistance of the ground to the penetration of a pile, which includes the modulus of elasticity of the pile, and involves the solution of a quadratic equation.[1] This formula has no value for practical men, who require something simple, and of easy application. So long as a pile is able to penetrate the ground, it is evident that the more dense the medium through which it passes, the greater will be the pressure on its sides, and consequently the greater the force required to draw it. At the same time, the more compact the

[1] *Vide* "Useful Rules and Tables relating to Mensuration, Engineering, Structures, and Machines," 4th ed., 1873, p. 183.

ground, the greater resistance it offers to the penetration of the pile. Hence any formula founded on the above data is valueless when a pile, on being driven, meets with an impenetrable obstruction.

With a view to throw light on this subject, the Author made a series of experiments (*vide* Appendix), from which it would appear that it is practicable to drive piles so as effectually to resist the action of a specified force tending to draw them from the ground. These experiments indicate that the force capable of drawing a pile is directly as the weight of the ram employed in driving it, and the space through which the ram acts; and inversely as the distance the pile is driven by the blow, and the circumference or perimeter of the cross section of the pile. From these data a co-efficient has been deduced, a mean of forty experiments giving ·3285 as the value.

Let W = the weight in lbs. of the ram.
F = the space in inches through which it falls.
s = the distance in inches to which the pile is driven by the blow.
R = the force in lbs. required to draw the pile.
p = the perimeter or girth of the pile in inches.
C = the co-efficient.

Then

$$\frac{R \times s}{W \times F} \times \frac{p}{4} = \frac{R \times s \times \cdot 25\, p}{W \times F} = C \quad . \quad . \quad . \quad (1)$$

As a pile 1 inch square has a perimeter of 4 inches, $\frac{p}{4}$ appears in the formula,

$$\frac{W \times F \times C}{\cdot 25\, p \times s} = R \quad . \quad . \quad . \quad (2)$$

$$\frac{W \times F \times C}{\cdot 25\, p \times R} = s \quad . \quad . \quad . \quad (3)$$

In formula (3) R may represent the force which a given thickness of ice is capable of exerting, and any excess of that force which it may be considered necessary to allow for safety. These formulæ are simple, and although, no doubt, only approximate, still in practice they are likely to give results quite as satisfactory as any adaptation of Professor Rankine's more theoretical formula.

The experiments would have been more conclusive if extended

to larger piles and more powerful machinery, but as the Author could not readily procure assistance, he found it impossible to carry out the experiments to the extent he wished. From observation of works erected on piles driven by a ram whose weight and the space through which it acted were both known, and the distance a pile was driven by the last blow, as alleged by the foreman on the work, the Author is confident that the formula possesses some value when applied to piles of larger dimensions.

He had an opportunity, during the first three months of the year 1873, of observing the action of ice on the piles of a bridge, constructed during the previous year, across a river confined by a dam for the use of mills. The piles had been driven by a ram of 940 lbs. in weight, the space through which it acted was approximately 20 feet, and the piles were driven until the penetration declined to $\frac{1}{2}$ inch under each blow. The level of the water changed frequently, during the three months, to the extent of 1 foot to 2 feet. The piles held their ground, and the ice broke away until it had attained a thickness of from 15 inches to 16 inches, when the piles began to come up. Some held the ground until the ice had gained several additional inches in thickness, but eventually all yielded to the superior power of the ice, and the bridge became a wreck. The piles were about 12 inches in diameter. The force that the ice could exert on such a pile would be equal to the circumference of the pile multiplied by the thickness of the ice, and by the adhesion per square inch of ice to timber. As the temperature was very low at the time the piles were drawn up, the adhesion cannot be safely taken at less than the mean of five experiments marked "Freezing" in the table of experiments on ice in the Appendix, page 201 (No. 11 in that table, being imperfect, should be rejected). The mean value of the adhesion is 33·32 lbs. per square inch; then $37 \cdot 7 \times 15 \times 33\frac{1}{3} = 18{,}850$ lbs. And from the formula $\frac{W \times F \times C}{\cdot 25\, p \times s} = \frac{940 \times 240 \times \cdot 33}{\cdot 25 \times 37 \cdot 7 \times \cdot 5} = 15{,}806$ lbs., is the force capable of drawing the pile; but the weight of superstructure resting on each pile, about 3,000 lbs., should be added, which would make the force required to draw the pile equal to 18,806 lbs. Had the space through which the ram acted been ascertained with greater accuracy, this illustration of the formula would have been more satisfactory; but the driver was worked on the ice, and equal lengths of the piles did not project above its surface when the last blow was delivered, so that the space described by the ram was in some instances greater, and in others less, than 20 feet.

If the mean pressure of the ground on the sides of a pile were constant, it might be relied on as a simple datum for calculation; but it will be perceived by comparing the mean pressures shown in the tables of experiments, with the distances the piles were driven by the last blow, that the more dense the soil the greater was the pressure on the sides of the pile. The intensities of those pressures will vary from causes which cannot always be perceived; for instance, should a pile be clasped tightly between large boulders the mean pressure will be considerably increased; but should the point of the pile get broken or crushed in driving, the mean pressure on its sides may be much less than that found by the experiments, which is nearly 8 lbs. per square inch. As the adhesion of ice to timber appears to be about four times as great as the mean pressure of the ground, for equal areas, it may be assumed that the pile should be driven more than four times the maximum thickness of the ice.

The pressure per square inch on the point of a pile is no doubt greater than the mean pressure on its sides. It was ascertained, when drawing the piles, that after they had been lifted from 1 inch to 2 inches, and the points released, the mean pressure per square inch on their sides was about 3 lbs. less than when the point held the ground. The points of all the piles experimented on were four-sided, and in length were equal to twice the diameter of the pile. Points more taper than this should penetrate the ground with greater ease, and consequently ought to give a higher co-efficient; but they are weaker and more liable to injury than those employed in making the experiments, and cannot be considered of such general application. In ten of the experiments the points were wedge-shaped. the edge of the wedge being equal to half the diameter of the pile. As such points present a greater surface to the ground, where the pressure is most intense, it was expected that they would afford better results than those whose sides tapered equally to a sharp point, but the experiments do not show that they possess any advantage.

The experiments on ice were made when the temperature was from 10° to 12° below the freezing point. This was likely to give more satisfactory results with small piles than if the frost had been more intense, and the ice of greater thickness. The piles were suspended in a tub of water in the evening in an open shed, and allowed to remain until the morning, when they were forced through the ice with a lever carefully weighted; they were so suspended that several inches of their length projected below the under surface of the ice, which adhered to their sides only.

A coating of coal tar on the piles would cause them to absorb and radiate heat more rapidly, and thus assist in weakening the adhesion of the ice, without adding much to the cost of the structure; this would certainly be of value on the approach of spring, as at this season the ice has attained a maximum thickness, and piles which have resisted its influence up to that time, are then frequently drawn out of the ground.

[APPENDIX.

APPENDIX.

The piles in all the following experiments were of oak; their points were four-sided, and the length of each point was equal to twice the diameter of the pile. In ten cases the piles had wedge-shaped points, the length of the edge of wedge being equal to half the diameter of the pile. In the other experiments the ends tapered equally to a sharp point, and (with the exception of Nos. 38, 39, and 40) the sides were equilateral.

CYLINDRICAL PILE, 1 INCH DIAMETER.

Description of Point.	No. of Experiment.	Weight of Ram.	Fall of Ram.	Distance driven by last Blow.	Force that drew Pile.	$C = \frac{\cdot 25\, p \times R \times s}{W \times F}$	Length in Ground.	Mean Pressure per square inch on surface of Pile.	Mean Value of C.	Description of Ground.
		lbs.	feet.	inch.	lbs.		inches.	lbs.		
Wedge-shaped.	1	22	4	0·964	325	·2330	20·5	5·2	..	Compact sandy clay, wet.
	2	22	5	1·135	445	·3004	20·5	7·2	·2527	Compact gravelly clay, dry.
	3	22	5	0·787	480	·2247	22·0	7·2	..	Sandy clay, dry.
Equilateral.	4	22	4	0·850	450	·2845	20·0	7·5	..	Compact clay with stones and gravel.
	5	22	5	0·635	550	·2078	15·0	12·3	·2651	Ditto.
	6	25	5	0·885	522	·2421	17·5	9·8	..	Stiff gravelly clay.
	7	26	5	1·178	550	·3262	18·25	10·0	..	Compact sandy clay.

PILE 1 INCH SQUARE.

Description of Point.	No. of Experiment.	Weight of Ram.	Fall of Ram.	Distance driven by last Blow.	Force that drew Pile.	$C = \frac{\cdot 25\, p \times R \times s}{W \times F}$	Length in Ground.	Mean Pressure per square inch on surface of Pile.	Mean Value of C.	Description of Ground.
		lbs.	feet.	inch.	lbs.		inches.	lbs.		
Wedge-shaped.	8	23·25	4·0	1·211	235	·2550	18·0	3·4	..	1 foot surface soil, 6 inches clay and stones, ground wet, point injured.
	9	23·0	4·5	1·115	385	·3456	19·0	5·3	·3355	Clay and stones.
	10	23·0	5·0	0·905	620	·4065	19·0	8·5	..	Ditto.
	11	23·0	5·0	0·746	620	·3351	17·0	9·5	..	Compact clay.
Equilateral.	12	22·5	4·0	1·430	255	·3376	19·0	3·5	..	Compact clay, dry.
	13	22·5	5·0	0·790	570	·3335	18·25	8·3	·3360	Ditto.
	14	22·0	5·0	0·523	850	·3368	17·5	12·9	..	Compact clay, wet.

PILE 1·25 INCH SQUARE.

Wedge-shaped.	15	22·5	7·2	1·172	340	·2562	17·5	4·1	..	Surface soil and clay, wet.
	16	22·5	7·2	0·754	750	·3636	17·5	9·0	·3461	Hard gravelly clay.
	17	22·5	7·2	0·895	727	·4186	18·5	8·3	..	Compact clay and stones. Pile held tightly by stones.
Equilateral.	18	22·5	7·2	0·633	564	·2296	17·0	7·1	..	Clay and stones, pile injured, point broken.
	19	22·5	7·2	1·444	449	·4169	18·25	5·3	·3043	Compact clay, dry.
	20	22·5	7·0	0·940	535	·3326	18·25	6·3	..	Compact clay, wet.
	21	39·0	3·0	0·420	637	·2382	13·0	10·8	..	Clay, very hard and dry.

CYLINDRICAL PILE, 1·5 INCH DIAMETER.

Description of Point.	No. of Experiment.	Weight of Ram.	Fall of Ram.	Distance driven by last Blow.	Force that drew Pile.	$C = \frac{.25\, p \times R \times s}{W \times F}$	Length in Ground.	Mean Pressure per square inch on surface of Pile.	Mean Value of C.	Description of Ground.
		lbs.	feet.	inch.	lbs.		inches.	lbs.		
Equilateral.	22	39·0	6·0	0·711	1,162	·3466	22·25	11·7	..	Stiff sandy clay, dry.
	23	39·0	6·0	0·850	1,302	·4643	22·5	13·0	·4001	Stiff clay, with stones, dry.
	24	39·0	7·0	1·230	777	·3436	22·25	7·8	..	Ditto.
	25	39·0	5·0	0·804	8,102	·4461	20·5	12·2	..	Compact sandy clay.
						PILE 1·5 INCH SQUARE.				
	26	23·75	7·2	0·362	1,288	·3410	16·25	14·5	..	Stiff clay, with stones.
	27	23·25	7·2	0·452	822	·2776	15·0	10·1	·3380	Clay and stones, point broken.
	28	23·25	7·3	0·668	780	·3837	17·0	8·4	..	Compact sandy clay.
	29	23·0	7·3	0·667	705	·3500	16·5	7·8	..	Ditto.
						CYLINDRICAL PILE, 2 INCHES DIAMETER.				
	30	39	7·0	0·840	719	·2895	18·0	7·0	..	About 9 inches surface soil and 9 inches clay, ground wet.
	31	39	7·0	0·763	1,078	·3942	23·5	7·9	·3329	Surface soil, clay and stones.
	32	39	7·2	0·684	1,059	·3375	23·75	7·7	..	Compact sandy clay.
	33	39	7·2	0·541	1,232	·3105	23·5	9·0	..	Pile passed through 20 inches of stiff clay into sand.
						PILE 2 INCHES SQUARE.				
	34	39	7·2	0·602	742	·2651	22·0	4·6	..	Gravelly clay, wet, point injured.
	35	39	7·2	0·704	903	·3773	22·5	5·5	·3492	Clay and stones, point broken.
	36	39	7·2	0·526	1,232	·3846	21·5	7·9	..	Clay and stones.
	37	39	7·2	0·506	1,232	·3700	21·0	8·1	..	Ditto.

PILE 3·25 INCHES × 1 INCH.

Description of Point.	No. of Experiment.	Weight of Ram.	Fall of Ram.	Distance driven by last Blow.	Force that drew Pile.	$C = \frac{\cdot 25\, p \times R \times s}{W \times F}$	Length in Ground.	Mean Pressure per square inch on surface of Pile.	Mean Value of C.	Description of Ground.
		lbs.	feet.	inch.	lbs.		inches.	lbs.		
Taper of point, 1 in 4.	38	39	7	·985	532	·3399	21·0	3·4	..	Compact clay.
	39	39	7	·908	602	·3545	20·25	4·0	·3450	Clay and stones.
	40	39	7	·743	707	·3407	18·5	5·3	..	Ditto.

Description of Piles.	Number of Experiments.	Sums of Co-efficients.	Sums of Mean Pressure per square inch on surface of Piles.
			lbs.
Cylindrical, 1 inch diam.	3	0·7581	19·6
„ 1 „	4	1·0606	39·6
Square, 1 inch	4	1·3422	26·7
„ 1 „	3	1·0079	24·7
„ 1·25 inch	3	1·0384	21·4
„ 1·25 „	4	1·2173	29·5
Cylindrical, 1·5 inch diam.	4	1·6006	44·7
Square, 1·5 inch	4	1·3523	40·8
Cylindrical, 2 inches diam.	4	1·3317	31·6
Square, 2 inches	4	1·3970	26·1
Rectangular, 3·25 inches × 1 inch . .	3	1·0351	12·7
	40	13·1412	317·4
Means	..	0·3285	7·93

EXPERIMENTS ON THE ADHESION OF ICE TO TIMBER.

No. of Experiment.	Description of Piles.	Thickness of Ice.	Force that destroyed Adhesion.	Limit of Adhesion per square inch.	Remarks.
		inch.	lbs.	lbs.	
1	Square, 1 inch	0·75	63·5	21·17	..
2	" 1 "	0·8	77·5	24·22	..
3	" 1·5 inch.	1·4	247·0	29·40	Freezing.
4	" 1 inch	1·4	205·5	36·69	"
5	Rectangular, 1·12 inch × ·83 inch	1·4	205·5	37·63	"
6	Square, 1 inch	1·0	125·5	31·37	"
7	" 1·5 inch.	1·2	47·0	6·53	..
8	" 1·25 "	1·0	..	..	..
9	" 1·5 "	1·3	183·0	23·46	..
10	" 1·25 "	1·1	173·5	31·54	Freezing.
11	" 1 "	1·1	105·5	24·00	"

The adhesion of No. 7 was impaired by exposure to the sun for twenty minutes. The adhesion of No. 8 was destroyed by exposure to the sun for forty-five minutes. In making experiment No. 10, a crack extended from it to No. 11, which impaired the adhesion of the latter. These three experiments must therefore be omitted in taking the mean value of the adhesion per square inch. Pile No. 8 went down when the lever was laid on its head, the moment of the lever being 9·5 lbs. Experiments 7 and 8 show how rapidly heat absorbed by timber affects the adhesion of ice to it; the air at the time was so cold that the warmth of the sun's rays was hardly appreciable, and did not thaw the ice or snow.

No. 1,442.—"Notes of a Visit paid to some Peat Works in the neighbourhood of St. Petersburg in May 1875. By WILLIAM ANDERSON, M. Inst. C.E.

ABOUT 8 miles above St. Petersburg, on the left bank of the Neva, are situated the Abouchoff Steel Works, erected within the last dozen years, for the purpose of manufacturing ordnance, railway wheels and axles, and other things of steel. About 3½ miles south of the village of Alexandroffsky, the locality of the steel works, commences a vast extent of bog, formed originally, and, indeed, still forming, about the base of a scrubby birch forest, in which, however, the greater number of trees have long since been cut down. The subsoil is clay of small tenacity, drying to a whitish colour. Serious attempts to utilise the peat on a large scale have only been made within the last few years, when the demand for a pure and cheap fuel for the steel works had become pressing. Under the immediate management of Captain Federoffsky, I.R.N., the works have been commenced quite on the edge of the bog, where the layer of peat is only 4 feet thick, of which a depth of 2 feet is compact black peat and the remainder peat of a soft mossy nature. Farther on the bog is said to reach a thickness of 18 feet in alterate layers of compact and mossy turf, the latter always being surcharged with water. The bog, when cut, is of a yellowish colour, but soon turns black on exposure to the air. The upper layer of bog is cut into cubes and wheeled away to be spread out and dried. The compact part is obtained in the same way, by spade labour, wheeled in barrows up an inclined plane, and shot on to a stage, from which it is shovelled into two horizontal pug mills, each of which delivers two streams of mashed and mixed peat, about 6 inches by 4 inches in cross section. These are at once shovelled on to low trucks, or trollies without sides, and run along rude railways, composed of flat iron bars, screwed to longitudinal timber sleepers, to the drying-ground, where the mass is formed by hand labour, mostly that of women, into bricks, 13 inches by 8 inches by 4 inches, in wooden moulds. After three days of dry weather the bricks are turned, then tilted up into little heaps, and finally, when dry, after about four to six weeks' exposure, stacked away for delivery in winter. The pug mills are about 18 inches in diameter and 7 feet long,

but the following was given as a better size:—Diameter of screw 26 inches, diameter of shaft 8 inches, pitch of screw 8 inches. The screws are not continuous, but each turn is pitched 14 inches from its neighbours. The number of revolutions 12, of blades seven; the length of the barrel 9 feet; the clearance between the screw and the barrel ½ inch. Besides the screws, there are also, secured to the casing, four sickle-shaped knives very strongly made, between which, and almost in close contact, pass similar blades fixed on the screw shaft, their use being to cut up any roots that may happen to get into the mills. The two mills actually in operation were easily driven by a Clayton and Shuttleworth 10-horse portable engine, working under 35 lbs. to 60 lbs. of steam. The produce of the two machines is said to be 30 cubic fathoms (of 7 feet), equal to 10,290 cubic feet of undried pugged turf in ten hours. The turf made last season into balls, about 3 inches in diameter, weighed 32½ lbs. per cubic foot, measured as dried and stacked. The amount of moisture and ash permitted in the turf furnished to the steel works is 25 per cent., of which quantity ash constitutes from 3 per cent. to 5 per cent. In the month of May the turf, as dug, contains 75 per cent of moisture. It is expected that above 4,800 tons of dry turf will be produced in the present season of one hundred days, and to dry this quantity an area of 70 acres will be required. The price is 8 kopecks a pood; delivered 3½ miles to the steel works, the carriage costing 1¾ kopeck per pood,[1] making the cost 13*s.* 9*d.* per ton; at this price it just competes with wood, the present price of which is 1*s.* per 8·4 cubic feet, as stacked, while Newcastle coal, used in the Siemens-Martin furnaces, at 27*s.* 5*d.* per ton is more expensive than either wood or peat. It is doubtful if turf can be produced at a profit at the price quoted above; much depends upon the weather, although this is generally favourable, the rainfall not exceeding 17·6 inches per annum, and amounting to only 8 inches for the months of May, June, July, and August. Captain Federoffsky lives in a small cottage built on the edge of the bog, and has about one hundred and fifty workpeople lodged in barracks specially built for them. Although most of the work is done by piecework, he has to feed the labourers on account of the difficulty of getting supplies to so out-of-the-way a place. He is of opinion that nothing except the rudest and cheapest appliances can be used profitably. The machines were originally constructed to mould

[1] One kopeck per pood is equal to 1·712*s.* per ton when the exchange is 33⅛*d.* to the rouble. 62·03 poods are equal to 1 ton.

the turf bricks, but the cost of subsequent handling was so great that the present rude process was adopted as more economical. Extensive sheds were erected to dry the turf under cover; these have all been abandoned on account of the heavy first cost and labour in carrying and placing the peat on the drying racks. Excavating machinery for getting the turf is quite out of the question, on account of the large quantity of tree roots present in the bog; these roots, however, more than pay for their extraction, because they form an excellent fuel, and are, in fact, exclusively used in firing the portable engine.

It has been found economical to kiln-dry the wood used in the puddling and reheating furnaces. In the Siemens-Martin producers wood can be used one year after being cut, and the peat with the 25 per cent. of ash and moisture specified. The peat is said to produce excellent gas. The rude tramways are easily shifted about over the drying-ground, and the mashing machinery is also constructed so as to follow the face of the bog as it recedes before the excavators.

In the Proceedings of the Russian Technical Society for May, 1870, M. Keerayef, at that time Chief Engineer of the Abouchoff Works, gives the results of experiments on the evaporative powers of coal, damp and dry wood, and turf. The trials were carried out in some two-flue Cornish multitubular boilers made at the Erith Ironworks, and of exactly the same form and dimensions as a boiler in use there. The shells were 20·2 feet long, 6·5 feet in diameter, the two furnace flues 14·56 feet long, 2·5 feet in diameter, each terminating in thirty-seven tubes of 3 inches external diameter and 5·64 feet long. The total effective surface was 696 square feet, calculated to be competent to evaporate 45·4 cubic feet of water at 210° Fahr. per hour; the area of the grate surface being 30 square feet.

Two experiments were made at the Erith Ironworks in 1869 and 1870, with Newcastle and Welsh coal, and in May 1870 at the Abouchoff Works, with superior, small and dirty coal, with damp and dry wood, and in 1874 with peat moulded by hand into balls about 4 inches diameter, and air-dried till the moisture contained did not exceed 14 per cent.

Wood dried by artificial means should weigh 160 lbs. to the cubic fathom (7 feet), or 16·8 lbs. per cubic foot as stacked. The weight of damp wood, after having been cut one year, is 224 lbs. per cubic fathom, or 23·6 lbs. per cubic foot; the fuel was a mixture of red and white pine in billets, known as nine quarters of an arschine (equal to 5 feet 3 inches) of fire-wood.

Mr. Keerayef's experiments were made with the view of determining which was the most economical fuel for the steel works, and especially to ascertain the advantage, if any, of kiln-dried wood. The last line but one of the annexed table shows that kiln-dried wood is the cheapest fuel, next comes damp wood, then the best quality of coal, then peat, and lastly inferior coal. The economy derived from using dry wood, as compared with damp, is very striking, amounting to 22 per cent.

TABULATED RESULTS of EXPERIMENTS on the EVAPORATIVE POWERS of VARIOUS KINDS of FUEL.

—	1.	2.	3.	4.	5.	6.	7.
Where experiments were made.	Erith Iron-works.		Abouchoff Cast Steel Works.				
Date of experiments	Dec. 20, 1869.	Mar. 25, 1870.	May 7, 1870.	May 23, 1870.	May 25, 1870.	May 26, 1870.	1874.
Kind of fuel used .	Good Newcastle coal.	Good Welsh coal.	Superior coal.	Inferior coal.	Wood cut one year; still damp.	Wood dried artificially.	Peat.
Fuel consumed per hour.	335 lbs.	351 lbs.	450 lbs.	515 lbs.	796 lbs.	538 lbs.	..
Cubic feet of water evaporated per hour at 100°·4 Fahr.	48	50	49·5	51	38·6	40·4	..
Pounds of water at 212° Fahr. evaporated per 1 lb. of fuel.	9·79	10·09	7·57	6·76	3·25	5·0	4·26
Cost of evaporating 1 cubic foot of water, in kopecks.	3	2·9	3·87	4·37	2·7	2·1	3·2
Ditto in pence.	0·960	0·928	1·238	1·398	0·864	0·672	1·024
Duration of experiment.	h. m. 5 25	h. m. 10 30	h. 4	h. m. 3 32	h. m. 3 48	h. m. 4 45	..

MEMOIRS OF DECEASED MEMBERS.

THE REV. ROBERT WILLIS,[1] one of the last of the brilliant circle of Cambridge professors, who, from the varied nature of their acquirements, were the glory of their University during the middle period of the present century, was born in London on the 27th of February, 1800. His father was Dr. Robert Darling Willis, Physician to George III., celebrated not only for his skill in restoring the king to health, but also for introducing, in conjunction with his brother, Dr. John Willis, that modern treatment of insane persons which substitutes gentle measures and cheerful surroundings for the system of restraint and cruelty formerly in vogue. As a child, Robert Willis's health was so delicate that he could not be sent to school; but he early manifested those tastes which were afterwards destined to distinguish him—becoming a skilful musician, a good draughtsman, and a most eager explorer of every ancient building that came in his way. When only nineteen years of age he took out a patent for an improvement to the pedal harp. In 1821 he became a pupil of the Rev. Mr. Kidd, of King's Lynn, and in the following year entered himself at Caius College, Cambridge, where he graduated B.A. as ninth wrangler in 1826. In the same year he was elected 'Frankland Fellow' of his college, becoming 'Foundation Fellow,' on the 9th of May, 1829. Mr. Willis now devoted himself to subjects in which pure mathematics were blended with physics and animal mechanism, to the last a favourite study with him. His papers in the Transactions of the Cambridge Philosophical Society, "On Vowel Sounds and on Reed Organ Pipes" (1829), and "On the Mechanism of the Larynx" (1832), amply testify to his acquirements in this branch of science. In 1830, Mr. Willis was made a Fellow of the Royal Society, and in the following

[1] The substance of this memoir is taken from a notice by Mr. J. W. Clark, nephew of Professor Willis, in the "Cambridge Chronicle," March 6, 1875, supplemented by professional details contained in an account of Professor Willis's life and works published in the "Newcastle Daily Chronicle" for August 27, 1863, during the meeting of the British Association; and in the "Architect" of March 6, 1875.

year became one of the original members of the British Association, which had just begun its career under the presidency of Earl Fitzwilliam. In this capacity he prepared a report on the then state of knowledge concerning the phenomena of sound, which was delivered orally at the meeting at Oxford in 1832. In 1837, Mr. Willis, without opposition, succeeded the Rev. W. Farish as Jacksonian Professor. Mr. Jackson's very curious will insists that his "lecturer, professor or demonstrator shall be the person best qualified by his knowledge in natural experimental philosophy, and the practical part thereof, and of chemistry, to instruct the students." The choice of subject is therefore practically left to the holder of the office for the time being, and Mr. Willis chose, as his predecessor had done, Applied Mechanics. His practical knowledge of carpentry and machinery, his inventive genius, and his power of lucid exposition made him a most attractive Professor, and his lecture-room was always crowded. No matter how dry the subject, he knew how to make it interesting; and whether he discoursed of rope-making or the organ, on joints or the Jacquard loom, he held his audience spell-bound, and dismissed them charmed alike with the knowledge they had gained, and the pure English in which it had been conveyed to them. In these lectures he first separated the principles of motion and force, in which course he was shortly afterwards followed by Dr. Whewell. His views on this subject were further developed and elaborated in his celebrated "Principles of Mechanics," which at once took its place as the most complete treatise that had yet appeared on the science of machinery, and raised its author to the highest rank as a mechanical philosopher.

In 1837, Professor Willis read to the British Association a valuable paper on the Teeth of Wheels;[1] and in the following year the subject was elaborately treated in a paper read by him before this Institution, when he produced his well-known 'odontograph.'[2] Although the investigation of the proper curves to be given to the cogs of wheels had long been a favourite pursuit of mathematicians, Willis nevertheless pointed out new forms possessing more general properties than any which had been previously employed. The odontograph is now very generally employed for enabling workmen to find at once the centres from which the two portions of the teeth are to be struck, so that they may work together truly.

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[1] *Vide* Report of the British Association for 1837, p. 152.
[2] *Vide* Trans. Inst. C.E., vol. ii., p. 89.

In 1849, a Royal Commission was issued to inquire into the application of iron to railway structures; and of this commission Professor Willis was appointed a member, Lord Wrottesley, Captain (now Sir Henry) James, Mr. George Rennie, Mr. (afterwards Sir) William Cubitt, and Mr. Eaton Hodgkinson, being his coadjutors, with Lieutenant (afterwards Captain) Douglas Galton as secretary. Professor Willis constructed an apparatus by which the phenomena indicated in the experiments were developed and made capable of practical illustration. His mathematical theory showed that the increased pressure produced by the greater velocity of a passing load, highly developed when slender elastic bars were employed, became unimportant in massive structures. This apparatus was subsequently exhibited at the meeting of the British Association in 1849. Professor Willis took an active part in the first Great Exhibition, of which he was one of the jurors, and drew up the report for the class of manufacturing machines and tools. In that capacity he contributed a lecture to the series which was organised by the Society of Arts in 1852. He was also Vice-President of the Paris Exhibition of 1855, and Reporter of the class for the machinery of textile fabrics; and, in connection with this office, published in 1857 a report on machinery for woven fabrics, for which he received the cross of the Legion of Honour from the Emperor Napoleon III. When the Government School of Mines was established in Jermyn Street, in 1853, Professor Willis was engaged as the Lecturer on Applied Mechanics, in which capacity he annually delivered a course of thirty-six lectures, and in every alternate year an additional course of six lectures to working men. In 1851, Professor Willis published a description of a system of apparatus for lecturers on experimental philosophy and mechanism, which he had matured during his own courses of Cambridge lectures; and he was now authorised by the Board of Trade to devise and construct new and improved forms of apparatus for teaching machinery. Many of these improvements are exhibited in the South Kensington Museum.

In 1862, Professor Willis was President of the British Association, which that year met at Cambridge; and in the following meeting at Newcastle, he presided over the mechanical section.

But great as is the indebtedness of the engineering profession to Professor Willis, it is far less than that of its elder sister, Architecture; and it is as an investigator into the architectural history of individual ancient buildings that his reputation will live, when the memory of his achievements in mechanical science may have faded. By profession a clergyman, by position Jacksonian Pro-

fessor of Natural and Experimental Philosophy in the University of Cambridge, he took up the study of architecture as a relaxation, and approached it from the antiquarian's, not the practician's, side. His was essentially an inquiring mind; he was keen in research, acute in observation, and logical in judgment, and his mathematical training qualified him to comprehend and to unravel the complications of constructions of even more than ordinary complexity. His learning as an antiquary, his familiarity with Mediæval Latin, his knowledge of the handwriting of mediæval scribes, and his perseverance in following up the very slightest clue, combined to render him eminently fit to investigate subjects towards which attention had forty years ago been only newly turned. The value of his early work, written during his wedding tour, and published in 1835, called "Observations on the Architecture of the Middle Ages, especially of Italy," must not be measured by its importance to the student at the present day. Other labourers in the same field have produced works which are certainly more modern, but none which are so comprehensive and which go so thoroughly to the root of the matter, dissecting a building as an anatomist does an organism, and laying bare the principles of its construction. If the work should appear at the present day to be somewhat old-fashioned, it should be remembered that Willis laboured on all but untrodden ground; and what he did was done completely and faithfully as far as it went. A subsequent essay on Gothic vaulting, which forms one of the ornaments of the "Transactions" of the Royal Institute of British Architects, may be accepted as a better specimen of the man and his method of working. Here the subject was a limited and a difficult one, and if the whole field is not occupied, that portion at least to which the main part of the essay was devoted is surveyed with an accuracy and a completeness which may be said pretty nearly to have exhausted it. This paper, read in 1842,[1] developed by the help of many years' personal observation and study, indicated the methods pursued by the ancient workmen in shaping the stones. It was followed up by the exhibition before the same body of his 'cymagraph,' an instrument invented by himself to obtain exact drawings of the profiles of existing mouldings. In the two following years he contributed to the Cambridge Antiquarian Society papers "On the Sextry Barn at Ely lately demolished," and "On the Architectural Nomenclature of the Middle Ages." A considerable part of the latter contribution was subsequently incorporated

[1] *Vide* Trans. Inst. Arch., 1842. p. 1.

in the fifth edition of the "Oxford Glossary," of which Professor Willis was the editor. In 1845 he published an elaborate "Architectural History of Canterbury Cathedral." This work was the substance of his discourse the year before to the congress of the Archæological Institute at Canterbury—the first of a series of oral lectures which he subsequently delivered almost every year to the members of that society at their successive congresses. The publication of the "History of Canterbury Cathedral" was followed by the delivery of discourses on the Cathedrals of Winchester, York, Norwich, Ely, Lincoln, Salisbury, Oxford, Wells, Chichester, Gloucester, Lichfield, Peterborough and Worcester, besides one on the "Architectural History of the University of Cambridge," when he held the office of Sir Robert Rede's lecturer in 1861. The last of this series, "On the Architectural History of the Cathedral and Conventual Buildings at Rochester," was delivered in 1863. In 1849, he published "The Architectural History of the Holy Sepulchre of Jerusalem," inserted also in the second edition of Williams's "Holy City." This is by no means an exhaustive catalogue of Professor Willis's contributions to architecture and archæology. Scattered up and down the transactions and the journals of the learned societies, his papers and discourses would fill many volumes. These important inquiries in the domain of architectural archæology obtained for Professor Willis the well-merited honour of the Royal gold medal of the Institute of Architects: and his acquirements in astronomy were such as to lead to his nomination by the President of the Royal Society as Visitor to the Royal Observatory at Greenwich, on the death of his great contemporary Whewell.

Professor Willis was elected an Honorary Member of the Institution of Civil Engineers on the 8th of May, 1838; he was also connected with many other scientific societies. His death occurred from bronchitis, on the 28th of February, 1875, after an illness of a few days.

MR. JOHN WILLIAM BLACKBURNE, eldest son of the late Mr. John George Blackburne, M. Inst. C.E., was born in Oldham on the 3rd of July, 1839, and was educated at Furness. When fifteen years of age, he entered the office of his father, and on the completion of his articles he had acquired considerable experience on the various railways, waterworks, and collieries then under his father's superintendence.

At the beginning of the year 1862, Mr. J. W. Blackburne was

made a partner, and took an active share in the business; the principal works on which he was engaged being the railways between Hyde and Hayfield, Stockport and Wordley, and Oldham and Guide Bridge, together with the waterworks at Glossop, Ashton, and Staleybridge, &c. In the spring of 1865, after an attack of smallpox, hemorrhage of the lungs ensued. Having rallied somewhat, his medical advisers proposed a voyage to Australia. Shortly after his return a recurrence of the symptoms took place, and it was not till 1868 that he was able to resume any duties, and then all active work was forbidden. He continued, however, to superintend the office department, and compiled a set of hydraulic and other tables, published in 1870. On the death of his father, in 1871, the principal charge of the practice devolved upon him, but the attacks of hemorrhage becoming more frequent, and in the hopes that a total cessation from business might afford relief, he retired to Burleydam near Combermere Abbey, Cheshire. Little or no benefit accrued from the change, and early in August 1874, he sustained an attack of more than ordinary severity, and died on the 17th of that month.

Mr. John William Blackburne was a most zealous supporter of the Volunteer movement, and joined the Oldham corps on its formation in December 1859. Having passed through the various grades, he eventually became captain in the regiment of which his father was lieut.-colonel. He was elected a Member of the Institution of Civil Engineers on the 7th of December, 1869.

Mr. JABEZ CHURCH, son of a well-known engineer of the same name, was born in London on the 2nd of April, 1824. As a youth he was of a studious disposition, greatly affecting mechanical and geological subjects. On arriving at manhood, these proclivities, being pronounced, determined him to follow the profession of a Civil Engineer. After the usual preliminaries, he obtained the appointment of Engineer to the Chelmsford Gas Company, and the connection thus begun continued throughout his whole career. The company's affairs were at the time in an indifferent condition, but from the moment Mr. Church took them in hand they began to flourish, and the concern is now a most successful undertaking. Mr. Church thoroughly understood and liked his branch of the profession, and soon made himself a reputation as a safe and trustworthy man to consult in all matters relating to it. He was largely interested in gas engineering generally, having constructed or been appointed Consulting Engineer to

nearly all the gas companies in his own county, as well as to many others in various parts of the kingdom. Among them, the Dublin Gas Company owes much to his skill and enterprise. He did not, however, confine his attention to gas alone, but designed and carried out the water and drainage works of many towns and villages. He was also frequently engaged in giving evidence before parliamentary committees, and as he was conversant with the tactics of the committee-room, his services as a parliamentary engineer were much in request. Even under the most severe cross-examination Mr. Church was always imperturbably good-tempered, and this, combined with his known attainments, and a certain air of authority derived from a commanding presence, gave great weight to his evidence.

In 1871 Mr. Church was made President of the British Association of Gas Managers, in whose welfare he took great interest. He was elected an Associate of the Institution of Civil Engineers on the 7th of February, 1854, and was transferred to the class of Member on the 1st of March, 1870. He was also a Fellow of the Geological and other scientific societies. For nearly a year he had been in failing health, and during the last six months of his life had been entirely laid up. His death took place on the 20th of May, 1875.

Amid the distractions of an active professional life, and while his services were in request all over England, in Wales, in many parts of Scotland, and in Ireland, Mr. Church yet found time to take his share of the public work of Chelmsford. He was a member of the Local Board of Health, likewise a valuable coadjutor to the vicar of Moulsham as his warden; and the poor have great reason to remember his benefactions. In this town he had built up a reputation as a Christian, a citizen, and a philanthropist. He was a man who could not fail to attract friends, his open countenance, and the cheerful, happy temperament which he preserved to the last, drew them to him, and, once gained, retained them. A fine specimen of an Englishman, in appearance and character, he fought the battle of life with honour, ability, courage, and energy, and as a reward attained conspicuous success.

Mr. THOMAS DALE was the eldest son of the Rev. William Dale, of Davenham, Cheshire, where he was born on the 9th of September, 1819. He was thoroughly educated by his father, especially in mathematics, as he was intended for a land surveyor. He had, however, a natural love of painting, and his youthful

mind was bent on the study of the fine arts. With this main object in view, young Dale toiled incessantly; but finding his efforts too circumscribed in a country village, he urged his father to send him to London. This was, however, opposed, and he was compelled to abandon the idea. He then accepted a situation in a merchant's office in Liverpool; but that occupation not being congenial, he decided upon becoming an engineer. After a preliminary apprenticeship, he, in 1845, was engaged on the Chester and Holyhead railway as contractor for tunnelling, sea-walling, iron and stone bridges, cofferdams, culverts, excavations, &c.; in 1849 as manager of extensive works of a similar character on the Manchester, Buxton, Matlock, and Midland Junction railway; and subsequently on the Liverpool waterworks as contractor for trench-work, paving, macadamising roads. In 1852 he was appointed Assistant Engineer on the Londonderry and Coleraine railway, to carry out the necessary tunnelling, sea-walling, bridges, viaducts, culverts, excavations, &c., and in the same year he made a complete survey of the river Moane, from Londonderry to Omah, to ascertain the water power available for the erection of flax-mills.

Mr. Dale then turned his attention to Municipal engineering, and became successively Town Surveyor of Tunstall (1853), of Leek (1856), and of Wakefield (1861). In these positions his duties consisted in making plans for, and carrying out works for sewerage, water supply, construction of new streets and roads, &c. While at Leek Mr. Dale made a trigonometrical survey of the town with a map to a scale of 1 inch to 88 feet. The Improvement Commissioners, highly satisfied with his execution of this work, presented him with an honorarium of two hundred guineas. In 1861 he was appointed Surveyor and Waterworks Engineer to the Corporation of Hull, which post he held for thirteen years. During this period he remodelled and extended the existing works for the water supply of the town, and designed and constructed new works at Spring Head, under difficulties such as to test the capabilities of any engineer. For these services he received a vote of thanks and gratuity of three hundred pounds from the Hull Corporation. In 1871 he was presented with a further honorarium of one hundred guineas by the corporation, and in succeeding years, until his connection with the corporation ceased, was engaged in additional extensions of the waterworks at an estimated cost of £30,000.

Mr. Dale took great interest in the question of the best means of supplying water to towns, and devoted much time and thought to a scheme for supplying the large industrial centre of the North with water from the lake districts of Cumberland and Westmore-

land. Prominent amongst the towns were Liverpool, Bradford, and Leeds.[1] This scheme was submitted to Parliament, plans were printed by the Government, and the evidence taken before the Royal Commissioners on Water Supply is recorded in their Report.

On leaving the municipal service Mr. Dale continued to reside at Hull, where he had acquired a considerable practice as a consulting engineer for waterworks, and in the short interval before his death was engaged by the corporations of Stafford and Walsall to oppose before a Parliamentary Committee Bills entitled "Stafford and District Water Bill and South Stafford Water Bill," when on the 18th of March, 1875, he was prostrated by an attack of heart disease, and died at the age of fifty-six.

Referring to Mr. Dale's connection with the town of Hull, "The Hull and Lincolnshire Times" of March 20, 1875, said:—"He had the courage, when he first took office in 1861, to pursue that line of action which his practical engineering skill dictated to him, and from which his predecessors had shrunk, and the 'British pluck,' which was his motto, carried him on to ultimate success in securing for the town an ample supply of pure water. No doubt his sudden deposition from the too-elevated seat he occupied in the confidence of his employers wrought upon his fine and sensitive spirit, and so accelerated his end; for ever since that time he gradually waned in physical strength. At one period he was surrounded by flatterers, who fawned upon him, and he repaid them with favours and hospitality. All at once he was deserted and loaded with the deepest of undeserved censure, which unquestionably preyed upon his mind, until death came with friendly care and put a period to his mental grief."

Mr. Dale was elected a Member of the Institution of Civil Engineers on the 2nd of February, 1869, and though seldom present at the Meetings, was active and energetic in furthering its interests in such ways as lay within his power.

Mr. GEORGE CLARISSE DOBSON was born in France in May 1801. His father and grandfather, both engaged in engineering pursuits, had for some time been resident in that country, and his mother was a Frenchwoman. Few particulars have been retained as to his earlier years. He was often heard to say that, as a boy,

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[1] *Vide* "On the Supply of Water to the Lancashire and Yorkshire Towns from the Lake Districts of Cumberland and Westmoreland." By Thomas Dale, C.E., Corporation Waterworks, Hull. 8vo. Hull, 1866.

he remembered entering Paris along one side of the Seine, while the Russians were entering it on the other. This would probably be in 1814. After this date he came to England and was apprenticed to Professor John Millington, whose "Elements of Natural Philosophy," 1838, once enjoyed considerable reputation. How long this apprenticeship lasted is not known; but there are evidences of it in the illustrations to Millington's "Epitome of Natural and Experimental Philosophy," 1823, the frontispiece to which bears Mr. Dobson's name; and it is understood that the whole of the lithographic plates, then much less used for purposes of illustration, were from the same hand. After this he appears to have been occupied in various forms of engineering work, and notably in mining operations, being certainly employed at the Lanescot mine, near Fowey, in 1829. From about 1831 to 1837, Mr. Dobson was chiefly engaged in assisting Mr. J. M. Rendel, Past-President Inst. C.E., and was occupied among other things on the drawings of the floating bridges established at Torpoint and elsewhere in 1832–34.[1] In 1839 Mr. Dobson was appointed by the Lords Commissioners of the Admiralty as Assistant and Draughtsman to Mr. W. Stuart, M. Inst. C.E., Superintendent of the Breakwater Department of the Plymouth Dockyard, succeeding Mr. Claringbull. In this capacity he continued until 1846, when, upon the recommendation of Mr. Rendel, he received from the Admiralty the appointment of Resident Engineer for the purpose of superintending the works to be carried out for the improvement of Holyhead Harbour, Mr. Rendel being the Engineer-in-Chief. At Holyhead, Mr. Dobson continued to perform his duties until the completion, in 1873, of that stupendous work. How much the undertaking owed to Mr. Dobson's undivided solicitude is not perhaps sufficiently known. Nor is it generally known that the original idea of the 'coal-scuttle' iron-tipping wagon, used at Holyhead, and since so successfully employed at Portland and elsewhere, was Mr. Dobson's. "I take this public opportunity," said Mr. Charles Rigby, Assoc. Inst. C.E., one of the Contractors for the works, at a dinner given in April 1857, "of stating that the credit of the invention of the iron-wagon is due to Mr. Dobson, who brought it out in a modest plan . . . . We made one full size, and tested its use. Napier and others had been scheming the mode of doing this, but the 'coal-scuttle wagon' has proved to be our best friend, and Mr. Dobson the best of all."

[1] An account of the Torpoint Floating Bridge is given in the Transactions of the Inst. C.E., vol. ii., pp. 213–227.

Mr. Dobson did not long survive the termination of the great work with which his name will mainly be associated. He died on the 29th of November, 1874. This brief and imperfect notice of him cannot better be concluded than by quoting some words used elsewhere: "The long usefulness of lives like Mr. Dobson's consecrated entirely to the carrying out of lengthy constructions, is often in danger of being overlooked in comparison with more varied or less unobtrusive careers. But many are still alive who will remember his undeviating integrity of purpose, and can recall the pride and courtesy with which, in the earlier and more active days of the works especially, he explained and exhibited their details to visitors."[1]

Mr. Dobson was elected an Associate of the Institution of Civil Engineers on the 31st of March, 1840, and was transferred to the class of Member on the 13th of March, 1849. He left a daughter and five sons. One of them, Mr. Hamilton Stuart Dobson, died recently in South America, while engaged in surveying the Brazilian coast under the direction of Sir John Hawkshaw, Past-President Inst. C.E.

MR. GEORGE JAMES HERVEY GLINN, the youngest son of Mr. P. Glinn, was born on the 11th of June, 1829, at Keyham near Plymouth, where his father was ordnance storekeeper. He served a regular pupilage, from 1846 to 1849, under Mr. R. Townshend, M. Inst. C.E., the Resident Engineer superintending the construction of the Keyham docks, factory, &c., and with whom he remained until 1854. At the latter date he was appointed by Mr. J. M. Rendel, Past-President Inst. C.E., an Assistant Engineer on the East Indian railway, and proceeded to Calcutta to join the staff of Mr. G. Turnbull, M. Inst. C.E., Chief Engineer of that line. After four years' service as an Assistant Engineer, he was promoted to the grade of Resident Engineer, and in that capacity had charge of works until 1863. He then joined the Indian Branch Railway Company, and superintended the construction of 30 miles of railway from Nulhatee to Azimgunge. He was then transferred to the Oude and Rohilcund line, and employed in making preliminary surveys for that line until 1864, when he was compelled by ill-health to return to England. In 1868, upon the recommendation of Mr. Lee Smith, M. Inst. C.E., Chief Engineer

[1] "Nautical Magazine," January 1875, on the appointment of a Harbour Master at Holyhead.

of the first Indian "State" railway, Mr. Glinn was appointed a first-class Executive Engineer to the railway then being commenced between Lahore and Peshawur. Upon this line during the last four years of his service in India he had charge of a district of 70 miles in length, and also of a division of 50 miles in length, both under construction, until, in the end of 1874, he was again compelled to take furlough on medical certificate. This relaxation unfortunately came too late. He never regained his health, and died at Plymouth, of liver complaint, on the 8th of April, 1875, shortly after his arrival at home. Mr. Glinn was greatly liked by all classes, whether superiors, equals, or subordinates; and his loss will be much felt by all who knew him in India, where he devoted the best years of his life to the interests of those by whom he was employed.

Mr. Glinn was elected a Member of the Institution of Civil Engineers on the 4th of March, 1873.

Mr. THOMAS LLOYD was born at Portsea, on the 29th of October, 1803. After receiving a preliminary education under the Rev. John Neave of that place, he gained admission, by competitive examination, into the "School of Naval Architecture," then located at Portsmouth Dockyard, where his father was one of the practical instructors. He entered this establishment on the 1st of June, 1819, and passed through the regular course of study with great distinction, leaving on the 1st of January, 1826. His first appointment was to Plymouth, now Devonport, yard, as a supernumerary officer, to acquire information as to the conduct of the general duties and business of the dockyards. Thence he was sent, in 1830, to the Navy Office, to acquaint himself with the practice of designing ships. In 1831 he made a six months' cruise in the "Columbine," a vessel forming part of one of the experimental squadrons, to obtain a practical knowledge of the behaviour of ships at sea.

Up to this time Mr. Lloyd had devoted his attention to the theory and practice of naval architecture, but he was now directed by the Admiralty to make a special study of the steam-engine and of machinery generally, with a view to his becoming an engineer. Accordingly, on his return from the cruise above mentioned, he was appointed Superintendent of the Wood-mills and Block Machinery in Portsmouth yard. Here he remained till the 19th of January, 1833, when he was gazetted Inspector of Steam Machinery at Woolwich.

In 1835 a new office—that of "Chief Engineer and Inspector of

Machinery"—was created at Woolwich, to which Mr. Peter Ewart[1] was appointed, and Mr. Lloyd was sent, on the 1st of July in that year, as his assistant, to Devonport, where he remained till the 27th of November, 1838. He was then again removed, in the same capacity, to Woolwich. In addition to his duties in these dockyards, he had to make periodical surveys of the machinery of all the mail-packets at their various stations. About this time he visited some of the principal engineering establishments in England and Scotland, to ascertain for the Admiralty their extent and capabilities. In 1842 Mr. Ewart died, and Mr. Lloyd was selected, on the 16th of November in the same year, to succeed him as Chief Engineer at Woolwich, a post which he held till the 6th of April, 1847, when he was removed to the Admiralty as "Chief Engineer of the Navy," a title subsequently changed to that of "Engineer-in-Chief of the Navy." It was during his second residence at Woolwich, viz., between 1840 and 1845, that he conducted the long series of important investigations and experiments which established the superiority of Sir Francis Pettit Smith's invention, the screw-propeller, over the paddle-wheels till then in use in the Navy.

At the close of the Exhibition of 1851, Mr. Lloyd and several of his friends were granted permission by the French Government to visit their arsenals, and the following gentlemen availed themselves of the opportunity of doing so in company:—Sir Joseph Whitworth, Bart., F.R.S., M. Inst. C.E.; Mr. John Penn, F.R.S., M. Inst. C.E.; Mr. Lloyd, C.B., M. Inst. C.E.; and Mr. Watts, C.B., who was at that time Chief Constructor of the Navy. The two latter went with the sanction of the Admiralty, in order to report on matters connected with shipbuilding and the manufacture of engines. At this time the "Napoléon" was being fitted out at Toulon. She was the first line-of-battle ship built expressly for the reception of screw engines of great power with a view to high speed. This led to the building, in this country, of the "Agamemnon," which ship, fitted with engines of 600 HP., attained a much higher speed than had been contemplated, and was in every respect justly considered a great success. When she was employed, in May 1858, with the United States frigate "Niagara," to lay the first electric cable connecting England with America, Mr. Lloyd was requested by the Atlantic Telegraph Company to join Mr. Penn and the late Mr. Joshua Field, Past-President Inst. C.E., in

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[1] For a memoir of Mr. Ewart, *vide* Minutes of Proceedings Inst. C.E., vol. ii. 1843), p. 25.

suggesting and carrying out such plans and arrangements as they should deem necessary for the safe paying out of the cable. The success which attended this undertaking is a matter of history. The subjoined letter will show how his services were appreciated by the company:—

"Atlantic Telegraph Company,
"22, Old Broad Street, London,
"22nd *May*, 1858.

"Dear Sir,

"I have laid before my Directors your letter of the 21st inst., wherein you state that you have no claim to make against this Company, and I am instructed to express to you their very warmest thanks for the kind and disinterested manner in which you have accorded to this undertaking your most valuable aid and advice, whereby in a great measure results at present so highly satisfactory have been secured in respect to the new machinery for paying out the cable.

"I am, dear Sir,
"Yours most truly,
"Geo. Saward, *Sec.*

"Thomas Lloyd, Esq."

When the combined French and English fleets were preparing to go to the Baltic in 1856, the late Emperor of the French conceived the idea of protecting the ships by shot placed in an external wooden case, and a target representing a portion of a ship's side so protected was erected at Vincennes. Mr. Lloyd accompanied Sir Baldwin Walker, the Surveyor of the Navy, and Mr. Watts, the Chief Constructor, to Paris, to witness the effect of artillery on this structure. It was on this occasion that the suggestion was made by Mr. Lloyd that more effectual protection would be afforded by solid armour plates. The idea was adopted by both Governments, and "La Gloire," built by the French, and the "Warrior," by the English, were the first types of a system of shipbuilding destined to revolutionise naval warfare.

In 1868 Mr. Lloyd received, as an acknowledgment of his eminent services, the honour of a Companionship of the Bath; and in 1869, after having completed fifty years of public service, he retired, on which occasion the following recommendation was addressed by Sir Spencer Robinson to the Treasury:—

"To state that Mr. Lloyd has discharged his duties with diligence and fidelity, and entirely to my satisfaction, would be but a feeble expression of my opinion of his deserts.

"Not only has Mr. Lloyd so discharged his duties as to entitle him to such an acknowledgment, but there is no public servant within my knowledge who has so largely contributed to the advance of practical science in his particular department.

"To Mr. Lloyd, more than to any one else, is due the successful application of the screw to the propulsion of steam-ships; and it was owing to his enlightened knowledge and his zealous exertions that the Royal Navy was enabled to take the lead in its application to ships of war.

"During a very long public life Mr. Lloyd has been distinguished for wise and carefully-considered suggestions for the improvement of the details of marine engines; and I venture to say that the principal marine engine makers in the kingdom have frequently consulted him, and always benefited by his advice.

"I do not hesitate to recommend Mr. Lloyd's case as one most specially deserving the greatest amount of consideration which it is in the power of the Treasury to bestow.

(Signed) "R. Spencer Robinson,
"*Controller of the Navy.*"

During his long and honourable career, Mr. Lloyd assisted by his judgment and counsel at all the various transformations the Navy has undergone in the present century. It must be borne in mind that, from the nature of his official position, he was necessarily rather a critic than an inventor, though there are few, if any, of those who were brought into contact with him professionally, who would not gladly testify to the value of the advice he was always willing to give, and to the courtesy and urbanity with which it was given. Perhaps those only who enjoyed the privilege of Mr. Lloyd's friendship and society could thoroughly appreciate him. His knowledge of a great variety of subjects, attained by diligent reading, and stored in a singularly capacious memory, will have been remarked by all his acquaintances; but those with whom he was intimate will remember, besides this, his ready wit, his hearty good-humour, and the pleasure he felt in doing a kindness. For several years before his death he had been in failing health, and almost entirely confined to his house, where he died in an apoplectic seizure, on the 23rd of March, 1875.

Mr. Lloyd was elected a Member of the Institution of Civil Engineers on the 18th of May, 1841, and was for many years a frequent attendant at the meetings, occasionally taking part in the discussions, and otherwise testifying to the interest he felt in its prosperity.

Mr. WILLIAM MARTLEY was born on the 4th of January, 1824, at Ballyfallon, co. Meath, where his family for many generations held a good position. He was a nephew of Lord Chancellor Black burne, formerly Chief Justice of Ireland. At an early age young Martley evinced great taste for mechanics; he was, accordingly, in 1841, articled to Mr. (now Sir) Daniel Gooch, at that time Locomotive Superintendent of the Great Western railway, and passed through the usual course of training at Swindon. On the completion of his articles Mr. Martley received an appointment as District Locomotive Engineer at Exeter. In 1847, he became Locomotive Superintendent on the Waterford and Limerick railway, which post he occupied for a few months only, leaving Ireland to take a similar position on the South Devon line. Here he remained until the opening for traffic of the first section of the South Wales railway, from Chepstow to Swansea, in 1850, when he was appointed Locomotive Superintendent of the company, and continued in that capacity during the several extensions of the line, the headquarters of which were established at Newport, Monmouthshire. During the "battle of the gauges" Mr. Martley was engaged in conducting the experiments undertaken on behalf of the broad-gauge interest by Sir Daniel Gooch, and was on the Midland engine when it was overturned during one of the experiments between York and Darlington, but fortunately he escaped with only slight injury.

When, in 1860, the East Kent railway had become of sufficient importance to obtain the sanction of Parliament for its extension to the metropolis, and to change its name to the London, Chatham, and Dover railway, Mr. Martley was chosen by the directors Locomotive Superintendent, and was subsequently intrusted with important duties in the organisation and supervision of the company's Channel steam service. He maintained his connection with the company till his death, which took place, after a short illness at Cedars Road, Clapham, on the 6th of February, 1874.

Mr. Martley possessed great ability as an engineer and superintendent; he was a man of strict honour and integrity, and was much beloved by his brother officers, friends, and workmen. He was elected a Member of the Institution of Civil Engineers on the 2nd of April, 1867.

Mr. EDWARD ADAMS was born on the 6th of June, 1814. He began his professional career as pupil under the late Mr. William Parsons, Assoc. Inst. C.E., Architect and Surveyor to the county of

Leicester. In 1836 he removed to London, where he was employed for five years and a half by the late Mr. Thomas Cubitt, the eminent builder, who was at that time rapidly covering with houses the estate of the Marquis of Westminster, known as Belgravia. Connected with building operations of the most extensive character, Mr. Adams had the best possible opportunity of making himself practically acquainted with the details of London house planning. So high an opinion did Mr. Cubitt entertain of his abilities that he intrusted Mr. Adams, then quite a young man, with the chief superintendence of the erection of the extensive factory at Thames Bank, Pimlico. On leaving this employ he went abroad for a considerable period with a view of improving himself in the artistic part of his profession, visiting in this way various parts of Italy, Sicily, and Greece. While in Rome he was made a member of the Artists' Club. Returning to England, in 1846, Mr. Adams received advantageous offers from his old employer; but decided to establish himself independently as an architect, which he accomplished, chiefly under the auspices of the late Mr. M'Clean, M.P., F.R.S., Past-President Inst. C.E., with whom he continued to be intimately associated during the whole of his professional career. Among Mr. Adams's undertakings may be mentioned a free grammar school, with houses attached, at Walsall, for which he was chosen Architect by competition, as was also the case with respect to the cemetery chapels at Wolverhampton; large pumping engine houses at Lichfield, and near Dudley for the South Staffordshire Waterworks; sheds for pumping and drawing-engines, church, parsonage house, and schools for pitmen's children, for the Cannock Chase Colliery Company; station and warehouses, on the Furness railway; buildings connected with the Eastbourne water supply, and numerous other works of a similar character. In 1857 Mr. Adams was appointed Architect to the South Staffordshire Railway Company, and in that capacity carried out stations, warehouses, dwelling-houses, and other buildings. He also designed the station on the Birmingham, Wolverhampton, and Dudley railway, and various other undertakings, including baths and washhouses at Paris. These works testify to the correctness of Mr. Adams's taste and his knowledge of construction; for the rest, he was of a quiet and reserved temperament, shrinking from notoriety, and leading a comparatively uneventful life.

Mr. Adams was elected an Associate of the Institution of Civil Engineers on the 7th of March, 1848, and he died in London on the 17th of March, 1875.

MR. THOMAS BELL was born in 1810 at Letheringsett, near Holt, Norfolk. At an early age he was apprenticed to his father, who carried on business as a millwright, and was engaged in putting up and repairing mills in the neighbourhood. In 1832, he removed to London and obtained employment with Messrs. Hunter and English, of Bow, as outdoor foreman, to superintend the sinking of wells and the erection of mill machinery. He had charge, among other works, of the sinking of a well at the Hampstead Road Reservoir, for the New River Company, a work attended with many difficulties, on account of the nature of the strata through which the well was sunk.[1] It was here that Mr. Bell brought himself under notice by untiring energy and by the tact he displayed, especially in the adoption of cast-iron linings for walling back the sandy soil. The well in question was 183 feet deep; and during the latter part of the work constant supervision was demanded, in consequence of the expectation that the chalk would soon be penetrated. On this being successfully accomplished, the water rose to a great height in the well.

After leaving Messrs. Hunter and English in 1839, Mr. Bell took charge of the erection of some machinery in connection with the Nottingham Old Waterworks, and was subsequently appointed Engineer to the company, which position he held until the year 1845, when the old and the new companies were amalgamated. He then became General Superintendent for the construction of the Bristol Waterworks under the late Mr. James Simpson, Past-President Inst. C.E., having also assisted in preparing the parliamentary plans and sections for the same. Here his sterling qualities were again displayed in surmounting the difficulties incident to the line of works, which extends over upwards of 16 miles, comprising tunnels, aqueducts in masonry and iron, and compensation and storage reservoirs. In the year 1851, Mr. Bell was appointed Resident Engineer to the Company, and occupied that position until his death. Latterly he was engaged in sinking a well at Chelvey, near Bristol, for the supply of the city, which, on account of the large quantities of water, had to be walled, but the work was successfully accomplished. While Engineer to the Bristol Waterworks, he brought out a waste-water-preventing valve, for water-closet purposes, which is still in extensive use.

Mr. Bell was elected an Associate of the Institution on the 4th of April, 1854, and, after some months of failing health, died in Bristol on the 19th of May, 1874.

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[1] *Vide* Transactions of the Inst. C.E., vol. iii., p. 229.

MR. WILLIAM CROSLEY, the only son of Mr. Richard Crosley—the representative of an old Yorkshire family—was born on the 12th of January, 1819, at Burnley, Lancashire, and was educated at the Grammar School of that place. He was brought up by his uncle, Mr. William Crosley, civil engineer; and in 1833, after a short term passed on the works of the Rochdale canal, began his professional career as an assistant to his uncle, who was engaged on the London and Birmingham railway under the late Mr. Robert Stephenson, M.P., Past-President Inst. C.E. Here he was employed until the completion of the works in 1838, the portion of the line executed under the elder Mr. Crosley's direction including the Tring cutting and the Wolverton viaduct. Subsequently, he was occupied in Mr. Robert Stephenson's private office, until he accepted an appointment on the Great Western railway under the late Mr. Brunel, Vice-President Inst. C.E., his duties extending over a district of 10 miles in length near Faringdon, Berkshire. Mr. Crosley was then invited to join the business of Messrs. Samuel and John Crosley, gas engineers and gas-meter manufacturers, and he remained with them in London from 1841 to 1845. Being disappointed in the fulfilment of the promises held out by his relatives, Mr. Crosley was thrown upon his own resources, and in 1846 accepted a position in Scotland under Messrs. Brassey, Mackenzie, and Stephenson, who were then constructing the Lancaster and Carlisle, the Caledonian, and the Scottish Central railways, besides other works. He became, in 1849, the London representative of Messrs. Tayleur and Company, of the Vulcan and Bank Quay Foundries, Warrington, which position he held till 1855.

In 1856, having patented an improvement in wet gas-meters, whereby the proper water-level was maintained in the measuring chamber, and made several additions, with the object of preventing meters being fraudulently tampered with, he established a gas apparatus and meter manufactory in Southwark Bridge Road. He promoted the Sale of Gas Acts of 1859 and 1860, whereby measures used in the sale of gas were stamped by Government inspectors. For this purpose he furnished some valuable statistics to the Parliamentary Committee appointed to inquire into the matter, and supplied the original cubic foot measure, transferrer, and gasholders for the Exchequer Office. Many similar measures were also made for various corporate towns in England and Ireland. In the early part of 1862 the business was disposed of to Messrs. Guest and Chrimes, of Rotherham. In the same year Mr. Crosley was appointed by Messrs. Brassey and Ogilvie the

Managing Agent to carry out the Moreton-Hampstead and South Devon railway, a branch 12¼ miles long, from the Newton Abbot station of the South Devon line. On its completion he was employed as Engineer in designing and carrying out the gasworks at Moreton-Hampstead—this being his last engagement. In 1869 his health began to fail, and after a protracted and painful illness his death occurred on the 28th of August, 1874.

Mr. Crosley was elected an Associate of the Institution of Civil Engineers on the 7th of May, 1850. He married, in 1847, Rosa Ann, the second daughter of the late Mr. John Gandell, the London representative of the Horseley Ironworks, near Birmingham.

Mr. Crosley possessed considerable practical skill in the execution of engineering work, and much ingenuity in mechanical construction; he was industrious and conscientious in the fulfilment of his duties, and deservedly obtained the confidence of his employers.

MR. EDWARD GERSHOM DAVENPORT, son of the late Mr. George Davenport, of Stoke Newington, in the county of Middlesex, was born in March 1838. His education was begun at University College School, and continued at King's College, which he left in 1856 for Trinity College, Cambridge. He graduated in mathematical honours in 1860, and on leaving the university was articled for three years to Mr. R. P. Brereton, M. Inst. C.E. Part of his pupilage was passed on the works of the Cornwall railway, under Mr. Blatchley, M. Inst. C.E., the Resident Engineer. On the expiration of his articles he was for five years chief assistant to Mr. Brereton. In this capacity Mr. Davenport had the general charge of the designs and specifications, as well as the subsequent execution, of various important works, including the harbours of Dartmouth, Porthcawl, and Neath, the drainage of Paignton, the Dartmouth and Torbay, Llynvi and Ogmore, and St. Ives and West Cornwall railways, as well as of numerous smaller undertakings. But at the death of his father in 1869, on succeeding to considerable property, he relinquished the active pursuit of the profession. In his new sphere of action he took especial interest in parish affairs, chiefly with respect to local taxation. While living in London Mr. Davenport was an energetic and much respected member of the Paddington Vestry and of the Board of Guardians of that parish. He was also on the committee of the Paddington Branch of the Charity Organisation Society, and took an active part in the election for the London School Board. Although in all these

matters he held and expressed strong opinions, he was able, from the kindness of his disposition, to keep on good terms with those from whom he most differed. The prominent part he played in promoting the welfare of St. Ives, Cornwall, in the neighbourhood of which he had assumed the position of a country gentleman, and his conscientious discharge of the duties devolving upon him as such, naturally pointed to him as a fitting representative in Parliament. Accordingly, at the General Election of February 1874 he became a candidate in the Conservative interest for St. Ives, and obtained the seat by a considerable majority. Mr. Davenport was no mere "aspirant for parliamentary honours," but one entertaining strong convictions, the result of much thought and study. Unfortunately a parliamentary career that opened well was destined to last but for a few months, Mr. Davenport dying on the 4th of December, 1874. He was elected an Associate of the Institution of Civil Engineers on the 4th of May, 1869.

Mr. RALPH ELLIOT, the eldest son of Sir George Elliot, Bart., M.P., M. Inst. C.E., was educated at the High School, Edinburgh, and, as a member of the firm of Messrs. Glass, Elliot and Company, had an active share in the development of submarine telegraphy. In the early days of the laying of submarine cables he accompanied the principal expeditions, and the first submarine lines between Malta and Alexandria, in the Baltic Sea, and elsewhere, were laid under his observation and partial superintendence. After the firm of Glass, Elliot and Company was merged into the Telegraph Construction and Maintenance Company, he accepted a seat at the board of the latter company; and also entered into partnership with his father for the manufacture of wire ropes for other than telegraphic purposes. In this latter firm, which is well known as George Elliot and Company, he was the managing partner from its commencement until his death, at the age of thirty-four, at Cape Town, while on a tour round the world for the benefit of his health. He was elected an Associate of the Institution of Civil Engineers on the 9th of January, 1866.

Mr. EDWARD BARBER HUMBLE began his apprenticeship to the engineering profession on the 2nd of August, 1841, when he entered the locomotive works of the Stockton and Darlington railway at Shildon, under the late Mr. John Dixon, M. Inst. C.E. During the last three years of his pupilage, which continued till 1847, he was Assistant Locomotive Superintendent. He had determined to seek his fortunes in India, a country then beginning

to attract attention as a promising field for engineers, of whom it wanted large numbers for the development of the railway system. Pending an advantageous offer, young Humble was for two or three years employed at various mechanical engineering establishments in the north of England, where he laid in a store of knowledge that afterwards stood him in good stead. In 1852 he proceeded to India for Messrs. Hunt, Bray and Emsley, contractors on the East Indian railway, and remained with them until 1857, when he was appointed Engineer to the Bengal Coal Company. This company meeting with but indifferent success, Mr. Humble, at the end of 1858, was appointed to the Engineering staff of the East Indian railway, and continued in the service of that company until his death, which occurred, from cholera, on the 12th of September, 1873. He was elected an Associate of the Institution of Civil Engineers on the 6th of February, 1866.

MR. JOHN PARSON, the son of Captain Parson, R.N., a member of a family of long standing in the West of England, was born on the 18th of February, 1816, at Launceston. He was articled to the late Mr. John Chappell Tozer, a solicitor in extensive practice at Teignmouth. Having completed his pupilage, he migrated to London, and joined the then firm of Messrs. Burchell and Kilgour, of Parliament Street. Messrs. Burchell, Kilgour and Parson were extensively concerned for railway companies, and Mr. Parson was thrown much into the society of civil engineers, by whom his intelligence and aptitude for business were highly appreciated. Amongst the undertakings of the firm, and of the conduct of whose affairs Mr. Parson had exclusive charge, was the Oxford, Worcester, and Wolverhampton railway. The company was labouring under great difficulties, the works were incomplete and at a standstill, and the promoters were without funds. For several years Mr. Parson's energies and services were mainly devoted to the business of that company; and having at length succeeded in completing the railway from Oxford to Worcester and placed the undertaking in a more satisfactory position, Mr. Parson retired from practice as a solicitor to join the Board of the company, in which he had acquired a considerable pecuniary interest. He shortly afterwards became its chairman, and continued in office until the amalgamation with the Great Western Railway Company relieved him from the cares which had so long and anxiously occupied his attention. Mr. Parson's services were soon enlisted on behalf of the Metropolitan railway. He became one of its earliest

directors, and, on the death of Mr. William Arthur Wilkinson (sometime M.P. for Lambeth), he was selected to fill the office of chairman, the duties of which he discharged with singular ability, and managed, under conditions of great financial difficulty, to raise, from time to time, the large amounts of capital necessary to complete that costly but useful public undertaking.

On his separation from the firm in London, Mr. Parson purchased the beautiful house and grounds of Bitton, at Teignmouth, where he became chairman of the Local Board of Health, devoting himself to the improvement of the town and the general interests of its inhabitants, by whom he was universally respected. He was a member of the Teignmouth Harbour Commission, and chairman to the Committee of Management of the Teignmouth and Shaldon bridge. He was elected an Associate of the Institution of Civil Engineers on the 21st of May, 1867, and he died at Teignmouth on the 6th of December, 1874.

MR. JAMES ALLEN RANSOME[1]—one of the leaders in a movement which, by bringing the science of the engineer to bear on the manufacture of implements for tilling the ground, has wrought, during the present century, an almost complete revolution in the practice of agriculture—was born in July 1806, at Great Yarmouth, where his father, the late Mr. James Ransome, was managing partner of a small foundry in connection with the now well-known "Orwell Works" at Ipswich. Born of a family in whom mechanical talent seems inherent, Allen Ransome was not long in showing the bent of his early genius. Accordingly, at the age of fourteen, he left school at Colchester to be bound apprentice to his grandfather, father, and uncle, who then carried on business at Ipswich, under the style of Ransome and Sons. After six years' practical training among a large body of working men, and the acquirement of a thorough knowledge of his business, Allen Ransome was transferred to Yoxford to manage a branch of the extensive business of the Ipswich firm. Whilst residing there he was the means of establishing the Yoxford Farmers' Club, the second of its kind in England, and for some time acted as its secretary, in which capacity he did much to promote the success and spread the reputation of the Club. He was one of the first in this district to introduce the "allotment system" for labourers, which, however coolly received at the outset, has come to be

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[1] This memoir has been chiefly prepared from notices in the "Suffolk Chronicle" of Saturday, May 1, and Tuesday, May 4, 1875.

generally adopted. About ten years later, he, with a few others, started the London Farmers' Club, the main features of which resemble those of the little Yoxford Club.

In 1829 Mr. Ransome became a partner in the house of which he had for some time been one of the managers. This took him once more into the neighbourhood of Ipswich, which town, however, he again forsook for Yoxford in 1833, ultimately returning to Ipswich in 1839, where he afterwards continued to reside as one of the leading partners of the firm of Ransomes and Sims. On leaving Yoxford he was presented with a handsome silver salver by the members of the Farmers' Club. It was during this period that those sterling qualities, energy, intelligence, and tact, for which Mr. Ransome was noted, fairly began to develop themselves. Early bred to business, under the example of an industrious parent, educated, in the best sense of the word, among hundreds of artisans, he was on arriving at maturity led to calculate the various and extensive means of usefulness which an active commercial life offered. It was fortunate for Ipswich and for thousands of working men that he was content to devote his talents to promote the agricultural and industrial arts, and to exhibit to all around that he was not unmindful either of the pleasure to be derived from the business, or from the duties devolving upon a large employer.

The Royal Agricultural Society of England was established in 1838, and Mr. Allen Ransome's name is to be found in the first short list of members. For at least twenty consecutive years, it is said, he never missed a show, excepting that held at Newcastle, nor was he often absent from the more important agricultural shows in the country; hence at all such gatherings he became a well-known figure.

The record of Mr. Ransome's life during the long period that he was one of the most prominent men in Ipswich would be the record of the town itself, for he was foremost in all movements that had its welfare for their object. For nearly thirty years he was a member of the corporate body, and for a considerable portion of that period he occupied an aldermanic chair. In this representative capacity he brought to bear shrewd common sense and an extended acquaintance with the requirements of the borough, tempered with an evident desire to study the pockets of the ratepayers. When a candidate for the town council, he boldly declared the opinion that municipal offices ought to be held independently of party politics, and that personal canvass during elections should be avoided. These were startling doctrines, but the good sense of the townsmen appreciated the spirit in which they were proposed, the result being that Mr. Ranso-

elected by a majority of more than fifty over his opponent. On the 9th of November, 1865, he was elected an alderman, and continued so until his death; but it was remarked as curious that he never could be induced to become mayor.

In estimating the character of such a man as Mr. Ransome, there are many difficulties, mainly arising out of its wonderful richness. Without being literally all things to all men, it may safely be said that in few, very few, instances could there be found such a power of pleasing and impressing men of very opposite kinds and pursuits. To hear Mr. Ransome amongst men of the world, one might believe that he was never absent from the worldly element in this life. To see him surrounded by more serious people, especially if they were bent on some philanthropical object, you would still find that he was a central figure. His large-hearted beneficence was tempered by shrewd discernment and a deep insight into human character. Of the good that he really wrought but little will ever be known; not that, by a refinement of Pharisaism, he was "ostentatious in concealing" his well-doings, but that his charity was incessant. It was his nature to do good, the quality being, in fact, but one of his common functions. He had an almost passionate desire for the education of the lower classes, and supported it by every means in his power. When a system of classes was started in Ipswich, Mr. Ransome was the life and soul of the movement. Did difficulties arise, he waived them aside; when debts were contracted, he paid them; and this not for one year merely, nor two, but on and on, till the Working Men's College was founded, and only a few can tell how much even that institution is indebted to his almost boundless liberality. Once it was doubtful if the classes could be continued. There were some who appeared to assist, but secretly disliked the project, and began to croak ominously that, as they had always predicted, the thing was going to pieces. A meeting of the supporters was called, which Mr. Ransome attended. The great difficulty, it was pretended, lay in the want of funds; but Mr. Ransome promptly produced his cheque-book and stoutly declared that want of money was not to be allowed to stifle a work which was doing good. He compelled the half-hearted ones to declare the deficiency, and wrote a cheque to meet it, on the sole condition that the work should be continued. But it was not only as a patron of their education that Mr. Ransome assisted the working men: he had laboured side by side with hundreds of them for years, till he knew their weaknesses and wants most thoroughly. Nothing that gave promise of affording to the working men the means of assisting themselves ever went without his help and advice. When the

Orwell Lodge of Odd Fellows, one of the most influential and important in the district, was established more than thirty years ago, Mr. Ransome took a lively interest in the project, and acted as the treasurer till the funds reached £500, paying at the rate of five per cent. per annum for all moneys deposited with him. From that period he was a trustee of the lodge, and annually examined the balance sheets, giving to the brethren the benefit of his knowledge of business on all occasions. To the Mechanics' Institution Mr. Ransome was ever a liberal patron. He deprecated the passing of the institution into the hands of a higher class than those for whom it was intended; but, nevertheless, was ready to assist it to the best of his power, though he personally wished to see it made somewhat different.

With some men the love of patronising their inferiors will constrain them to great depth of condescending charity, for the sake of the power it brings; but this was not the case with Mr. Ransome. For instance, though it was notorious that contests between employers and employed were and continue to be quite unknown at the Orwell Works, such immunity did not arise from any weakness in conceding every demand that might be made by either side, but was the healthy outgrowth of a judicious application of the good old maxim of bear and forbear, which was a tradition in the Ransome family. The ordinary relations between master and men did not obtain; the establishment, numbering between one thousand and two thousand hands, might rather be considered as a great family or clan, of which Mr. Ransome was the head, than a commercial undertaking. In the councils of the firm, if any proposition was brought forward to which one of the partners had an insuperable objection, it was not carried by force of numbers, but its consideration was deferred until there was a chance of unanimity. That the centre of such a harmony should be among the most honoured, loved, and respected men in Ipswich was natural; and it was a common saying, that the best music the inhabitants could hear was the rattle of his carriage through the streets.

About 1859 Mr. Ransome sustained an attack of partial paralysis, and for many years before his death he had lost the use of his lower limbs, his principal means of progression being an invalid chair; but so great were his animal spirits that he never allowed this deprivation to interfere with his active habits of business. ~~nd~~ what to many men would have been a most severe affliction, was with him scarcely noticed, save as a means of cracking many a joke against himself. He was a member of the Society of Friends, but he was far too genial to stickle for their conventional peculiarities; and it would be well if his liberality, as regards the religious

opinions of his fellow-men, were more generally diffused. Such a man was Allen Ransomé—a man of large sympathies and a woman's tenderness of heart. The personification of "gay wisdom," he was the pleasantest of companions. Frank and open, lovable and affectionate, his presence was welcome as a ray of sunlight, and his death was indeed a day of mourning for Ipswich.

Mr. Ransome had for some time been suffering from gout in the stomach, from which he knew recovery was hopeless. Though his sufferings must have been intense, the path to the grave was relieved with cheerful flashes from an ever buoyant temperament. Everything that loving solicitude could suggest or professional skill devise to stay the progress of the disease was tried, but in vain; and, after a struggle, the patient succumbed on the 29th of April, 1875, in the sixty-ninth year of his age. His funeral was an event in the history of the town of Ipswich. Most of the shops were shut in token of respect to the deceased; the whole of the employés of the Orwell and the Waterside Works, as well as others, attended, and the procession took twenty-five minutes to pass through the gates of the cemetery.

Mr. Ransome's connection with the Institution of Civil Engineers dates from the 3rd of March, 1846, when he was elected an Associate; he served on the Council in that capacity in the session 1858–9. He was the author of a standard work on "The Implements of Agriculture," of which he presented a copy to the library.

MR. GEORGE EDWARD WYTHES, only son of Mr. George Wythes, Assoc. Inst. C.E., the eminent contractor, was born at Portslade, near Brighton, in the year 1841, when his father was constructing the branch line of railway from Brighton to Shoreham. He was educated at Eton, and at Trinity College, Cambridge, and subsequently served a pupilage of three years to Mr. R. J. Hood, M. Inst. C.E. After this he assisted in carrying out some of his father's works on the Midland railway at Alfreton, Derbyshire, and in other places. Mr. G. E. Wythes was an active member of the Board of Directors of the Brighton Railway Company, and shortly after his decease his colleagues recorded in eulogistic terms their appreciation of his services to the company; he was also one of Her Majesty's Justices of the Peace for the county of Essex, a Poor Law Guardian, and a Verderer of Epping Forest. He was elected an Associate of the Institution of Civil Engineers on the 7th of February, 1865, and he died at his residence, Copt Hall, Essex, on the 2nd of March, 1875.

Sect. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

The Passes and Geology of the Central Pyrenees.

By M. Mille.

(Annales des Ponts et Chaussées, June 1875, pp. 508–514.)

The Pyrenees are at present traversed by two coast lines of communication. The one from Paris to Madrid skirts the shore from Bordeaux to Bayonne, crosses the Bidassoa and the Ebro near its source, and comes by Burgos on to the plain of Castille. This was the road taken by the armies of Napoleon, and is now traversed by the Northern railway of Spain. On the Mediterranean side the Southern railway of France goes from Perpignan to Barcelona, and as far as Valencia; it formed the old road to Italy taken by Hannibal. A passage across the centre of the chain still remains to be accomplished.

The valleys of the Pyrenees abound in marbles and iron ore, and the land, warmed by hot subterranean springs, produces abundant vegetation and valuable timber to a considerable altitude; but the means of transport are deficient, and would be best supplied by a central railroad with diverging lines. In the centre of upheaval the granite is covered by Silurian schists, often intersected by bands of white marble; above lie the Devonian schists, with the old red sandstone and marbles; next come the blue limestones, and a covering of nummulitic limestone forms the first slopes of the mountain range.

Four principal rivers descend on the northern side of the chain, the Ariege, the Garonne, the Neste, and the Gave. The valley of the Ariege at Ax contains an impenetrable barrier of granite, which blocks the way for a railroad. The valley of the Garonne presents the easiest course for a railway. It would be possible to reach Sabardu with inclines suitable for locomotives, a height of nearly 4,600 feet; from thence it would be necessary to rise by zigzags, or a steep incline worked by means of the water power of an adjacent torrent, up to the Plà de Béret, a large grass plain 6,170 feet above the sea-level. From this plain it might be possible to descend on the Spanish side by the valley of the Noguera Pallaresa to Lerida. If the valley of the Neste is followed, it would be necessary to branch off at Vieille Aure into the ravine of Moudang, and then, at

Cabanes, at a height of 1,740 feet, to tunnel through 3 miles of schist, coming on the opposite side into the valley of Bielsa, and thence to Barbastro. The valley of the Gave d'Oléron offers another course, and, passing along the line of the Somport road, a descent is made on the opposite side towards Jaca, and going by the valley of Gallego, Saragossa is reached. This being the most direct line between Paris and Madrid, passing by Perigneux, Pau, and Saragossa, is preferred by the Spaniards.

L. V. H.

Earthwork Experiments on the Sirhind Canal.

By J. D. Derry, Lieut. J. F. Miller, Major R. Home, R.E., and Col. J. Crofton, R.E.

(Roorkee Papers on Indian Engineering, April 1875, pp. 251–298.)

The circumstances of the Sirhind Canal involved the excavation through a plain of a channel about 200 feet wide, and of varying depth, the material from which had to be run to spoil into embankments parallel with the centre line; and it was to ascertain the most economical mode of working that these experiments were undertaken.

The cost of working by manual labour varied much, as will be seen from the following prices paid by contract for coolie and basket work:—

Lift.	Lead.	Cost per 1,000 cub. ft.		Cost per cub. yd.
Feet.	Feet.	R.	a.	*d.*
3	150	2	4	1·46
45	200	5	8	3·57
33	318	4	0	2·59
48	400	5	0	3·24

The rates paid for labour per day being—1st class men 4 a., or 6*d.*; 2nd class men, 3 a. 6 p., or 5¼*d.*; and for boys, 3 a., or 4½*d.*

The experiments, seven in number, were as follows:—

1*st Experiment.*—Barrows running on rails, and planks laid on an inclined road of 1 in 3; the work being carried on by an endless rope passing round two grooved wheels fixed at the top and bottom of the incline, upon which were swells or knots to catch a fork on the barrow, so that the weight of the man guiding the descending empty barrow drew up the full one.

This system was abandoned on account of the cost of materials, want of strength of the workmen, and because of the large quantity of plant required on a work of such magnitude; it was also found that the rope became unmanageable with a greater lift than 23 feet. The cost of working this system is not given.

2*nd Experiment.*—A beam 22 feet long, revolving parallel to a slope of 1 to 1 on a pivot at its centre, fixed at right angles to the incline, was so fitted that buckets or skips could be fixed to either

end in such a way that the weight of the empty skip and a workman at the top of the incline would overbalance the beam, and in their descent lift the full one to the top.

This system did not succeed on account of the want of weight of the workpeople, and the impracticability of working on a large scale with a greater lift than about 15 feet. No details of cost are given.

3rd Experiment.—With wagons of 5-cubic feet capacity, having cast-iron wheels 15 inches in diameter, running on a light railway of 18 inches gauge. There were two lines of rails up the slope of 1 in 3, 5 feet apart from centre to centre, one road being reserved for the full wagons, the other for the empties; between these roads at the top of the incline was fixed a grooved wheel 5 feet in diameter, the plane of revolution of which was parallel to that of the slope. Over this wheel ran an iron wire rope 1 inch in circumference, with hooks at each end, so that the full wagon was raised by the weight of the descending empty one, assisted by men pushing, the rope being shifted over after each ascent. There were placed at the top and bottom of the incline small cast-iron six-throw turntables, from which the roads ran to the faces of the excavation and the tips on the spoil bank. Mr. Derry states that with this system he has actually raised eight hundred wagons (3,600 cubic feet, or 133 cubic yards) a total height of 40 feet in a day of ten hours; and has worked at the rate of twelve hundred wagons (200 cubic yards), or two wagons per minute; but Major Home thinks that six hundred wagons (2,700 cubic feet, or 100 cubic yards), or one wagon per minute, is a fair average. With a lift of 52½ feet, and a lead of 661 feet, the actual cost, including plant, was 5 r. 2 a. 10 p. per 1,000 cubic feet, or 3·36*d.* per cubic yard.

4th Experiment.—In this case wagons of 25-cubic feet capacity were drawn up inclines of 1 in 2½ by wire rope on a drum worked by a stationary engine. This system was fully elaborated by Mr. Derry, and is well illustrated by drawings in the Paper; where it is compared in detail with Experiment No. 6, the distinguishing difference between the two being in the inclines, viz., 1 in 2½, as compared with 1 in 20 in Experiment No. 6.

The actual cost (not including allowance for plant) for a lift of 50 feet, and a lead of 500 feet, was as follows:—

	Per 1,000 cubic feet.			Per cubic yard.
	R.	a.	p.	*d.*
November, 1872	4	1	4	2·65
December "	3	6	6	2·21
January, 1873	3	4	5	2·12
February "	3	13	4	2·49
March "	4	5	0	2·80
April "	3	12	0	2·43
The average being	3	12	5	2·45

These prices, in the opinion of Colonel Crofton, are much higher than would be the case if more improved plant (which experience proved to be necessary) had been used.

5th Experiment.—The spoil in this experiment was raised to the top of the bank in the 5-cubic feet wagons described in Experiment No. 3, and then tipped into 25-cubic feet wagons, in which it was run to spoil, the work being performed by manual labour. This was the most economical arrangement where the lead was long, and it is still in use on the canal. Including allowance for plant, with a lift of 22 feet and a lead of 927 feet the cost was 4 r. 9 a. 9 p. per 1,000 cubic feet, or 2·99*d.* per cubic yard.

6th Experiment.—Wagons and motive power the same as in Experiment No. 4, but with inclines of 1 in 20. It is a modification of the plan proposed by Mr. Cheyne, and was worked out by Lieut. Miller, who introduced traverse carriages instead of turntables. This system laboured under the same disadvantages as regards want of proper appliances as No. 4, and is considered inferior to it, with the additional drawback of the difficulty of removing the earth from between the feet of the inclines. The cost, not including allowance for plant, with a lift of 40 feet was 3 r. 12 a. 9 p. per 1,000 cubic feet, or 2·46*d.* per cubic yard.

7th Experiment.—Wagons on long inclines, drawn by locomotive engines. This system has only been at work a short time, and no details are given.

At present the only systems at work are those described in Experiments 5th and 7th, and Colonel Crofton sums up the result of the experience gained in the following words:—

"It has been found . . . that the increase of rate for 1 foot of lift is equivalent to that for 6 feet of lead.

"One lesson is, I think, clearly taught by these experiments, that where mechanical appliances are to be used for excavation, it is very false economy to employ makeshifts. The plant should be designed and specially manufactured for the purpose. The engine lifts especially (Experiments 4 and 6), as stated above, never had a fair chance of succeeding, owing to the want of properly-made machinery and appliances."

A. R. B.

On the Best Form of Retaining Walls.

By Dr. H. Zimmermann.

(Civilingenieur, xxi., part 2, cols. 159–174.)

The question, what form a retaining wall must have in order to afford in each point the same security with the least possible amount of material, will be solved under two suppositions:—

1. The earth to be retained has no cohesion, and therefore does not project above the top of the wall.
2. The inner surface of the wall is a plane.

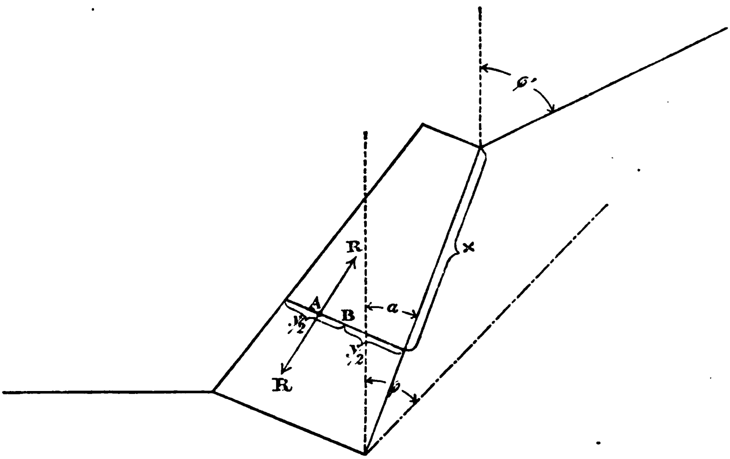
Let q be the weight of a cubic foot of earth, p the weight of a cubic foot of masonry, m a co-efficient referring to the thrust of the earth, which may be calculated in the usual way from the angle

of the natural slope ϕ, the angle a, and the angle of the slope ϕ' in the case of a surcharged wall, y the width in any point of the wall, and x the corresponding distance from the top.

As the inner surface is already determined by condition 2, it remains only to find the shape of the outline, which may be done in the form of an equation between x and y.

In each point of the wall the three forces, thrust of the earth, weight of the wall, and pressure (R R, Fig. 1) between the stones, must be in equilibrium, a condition which will be fulfilled if the line of internal pressure R lies in its whole length within the inner third of the cross section. In this case the joints have to resist only compressing, but not pulling strain.

FIG. 1.



The condition for security is therefore (Fig. 1),

$$AB \leqq \frac{1}{3}\,\frac{y}{2}.$$

If e be called the ratio between A B and $\frac{y}{2}$ there is equal security over the entire wall if e = constant.

By forming the equations for equilibrium between the three above-mentioned forces, the conditions for it are

(1). . . . . $y = b\,x$

wherein (2). . . . . $b = \tan\beta =$

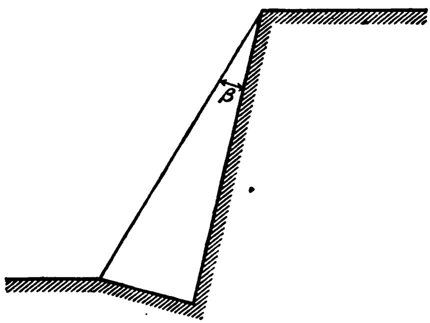
$$\left\{\begin{array}{l} -\dfrac{1}{1+3e}\tan a - m\,C_1\cos a \\ \pm\sqrt{m\,C_2\cos a + \left(\dfrac{1}{1+3e}\tan a + m\,C_1\cos a\right)^2} \end{array}\right\}$$

and

$$C_1 = \frac{3}{2}\,\frac{1+e}{1+3e}\,\frac{q}{p}\cos\phi, \qquad C_2 = \frac{2}{1+3e}\,\frac{q}{p}\sin\phi.$$

The outer surface of the retaining wall has to be a plane inclined under the angle $\beta = \text{arc}\tan b$ to the inner surface (Fig. 2). It will easily be seen that the amount of material required to build the wall decreases with the angle β, and that in consequence of equation 2, β increases if e increases. To obtain, therefore, the least possible amount of material, e must have the greatest value which the condition of security permits, viz., $e = \frac{1}{3}$.

FIG. 2.



Taking this as a standard, it follows

$$C_1 = \frac{q}{p}\cos\phi, \qquad C_2 = \frac{q}{p}\sin\phi,$$

$$(3) \quad . \quad . \quad . \quad . \quad b = \tan\beta = \left\{ \begin{array}{l} -\frac{1}{2}\tan\alpha - m\,\frac{q}{p}\cos\alpha\cos\phi \\ +\sqrt{m\,\frac{q}{p}\cos\alpha\sin\phi + \left(\frac{1}{2}\tan\alpha + m\,\frac{q}{p}\cos\alpha\cos\phi\right)^2} \end{array} \right\}$$

As the angle α in most cases is not strictly prescribed, it is possible to choose it in such a way as to fulfil special requirements.

If, for instance, further saving in material is desired, α must be increased, since, as shown in equation 3, β then decreases. But it is clear that whilst α is increasing, the horizontal space occupied by the wall increases likewise, and therefore the chief object of the retaining wall, viz., economy of space, is partly lost.

If this latter condition be the principal requirement, the angles α and β have to answer the equation

$$\tan\alpha + \tan\beta = \text{minimum}.$$

Sometimes the retaining wall is desired to be perfectly steady

before the space behind it is filled up with earth, in which case the inside surface has to be a vertical plane.

EXAMPLES.

1. Suppose $\alpha = 0$ and $\phi = 90°$.
The material to be retained is water; therefore

$$m = 1, q = 1.$$

Out of equation 2 follows

$$\tan \beta = \sqrt{m \frac{q}{p}} = \frac{1}{\sqrt{p}}.$$

If the weight of the masonry were twice that of the water, then

$$p = 2;$$
$$\tan \beta = \sqrt{0 \cdot 5} = 0 \cdot 701;$$
$$\beta = 35 \cdot 25°;$$

2. Suppose for earth:—

$$\phi = 55°$$
$$\phi' = 90°$$
$$q = p$$

Choose $\tan \alpha = \frac{1}{v \cdot f}$, $\alpha = 11° 20'$.

Determine m by calculation, or after Culmann's graphic method:—

$$m = 0 \cdot 172$$

Then is $\tan \beta = 0 \cdot 2238$
$\beta = 12 \cdot 6°$.

G. K.

Storage Reservoir for the Madrid Water Supply. By E. BOIX.

(Revista de Obras Publicas, Nos. 1–3, 1875, 11 pp., 2 pl.)

The Author briefly describes the existing dams of Ponton de Oliva and of Navarejos, and the purpose of their construction. The principal object of the former is to raise the water of the river Lozoya to the level of the intake of the canal. Its height is 92 feet, but as the quantity of water is still and increasingly inadequate for the service of the canal, as well as for the supply of Madrid, the construction of a reservoir was determined upon, large enough to provide for all wants even in the driest seasons. The site selected was 13·66 miles up-stream from Navarejos, where the river runs through a deep, narrow gorge, the sides and bottom of which are composed of very hard gneiss; and as the bed of the stream from thence to Navarejos is composed of gneissic, micaceous, granitic, and schistose rocks, the loss of water from filtration, although provided for in the calculations, could not be practically

demonstrated. The canal being 7·3 feet in width by 5·9 feet in depth, and having a fall 1 in 500, a calculation according to Bazin's formula gives a daily delivery of 48,840,000 gallons, and as the town does not require more than one-fifth, the rest can be applied to irrigation.

The evaporation, which had principally to be taken into account, was that which would obtain from the reservoir during the season of drought, lasting sometimes ninety days; the quantity evaporated from its variable area during that period was estimated at 28,382,178 cubic feet; a further quantity of 14,124,000 cubic feet was allowed for evaporation during the same period from the surface of the stream, assumed to be 65 feet broad and 13·66 miles long, while the rate of evaporation was taken at 0·0328 foot per diem. To this was added a possible loss of 3,531,000 cubic feet by filtration through the bed of the river between the Villar dam and that of Navarejos. The total volume allowed for loss was estimated at 46,044,240 cubic feet.

The quantity of water discharged by the river during the period of drought was very variable. The gaugings in 1868, an exceptionally dry year, recorded 93,006,540 cubic feet during eighty-eight days of drought, but only 70,620,000 cubic feet have been relied on in the calculations. From the above data the capacity to be given to the reservoir is as follows:—

	Cubic-feet.
Maximum supply to the canal during ninety days, at the rate of 7,838,820 cubic feet per diem	705,493,800
Losses of all kinds	46,044,240
	751,538,040
Water brought down by the river during ninety days	70,620,000
Capacity to be given to the reservoir . . .	680,918,040

In order to arrive at the total quantity of water available, that contained in the Ponton de Oliva reservoir, and that contributed by the feeders between the dams of Villar and of Navarejos, must be taken into account. The volume of water to be impounded having been determined, an examination of the river basin for 7·5 miles up-stream led to the adoption of 149 feet as the height of the dam above the bed of the stream. The total height of the structure somewhat exceeds this, because the surplus water was not to be discharged over the crest, and because the foundations upon the rock require a considerable mass of masonry. A roadway of 13-feet breadth, with a parapet 2 feet thick on each side, will be constructed on the top, at a height of 169 feet from the lowest point of the external or down-stream face. In plan it is curvilinear, the top edge of the up-stream face describing an arc of a circle of 442-feet radius.

A communication is established between the two banks of the

stream by an iron bridge over the waste weir, with a roadway at the same level as that on the top of the dam.

Ordinarily a waterway of small dimensions, provided with its corresponding sluice, would have been sufficient, but the river Lozoya brings down during freshets great quantities of mud and sand, which might accumulate at the entrance of the reservoir. To prevent this and to give a free passage to the water, when storage is unnecessary, the lower part of the dam has two waterways with inlets of about 11 square feet each. With 13 feet of head, these will be equal to a discharge of 705 cubic feet of water per second, a quantity exceeding the volume of the river in the winter and spring months.

The entrance to each waterway is by an arched opening, 4·3 feet wide, 2·95 feet in height, and 4·9 feet in length, communicating with a culvert 5·2 feet wide by 108 feet long, the floor of which has a fall of 3·28 feet. To diminish the great force required to handle sluice doors of more than 3 feet square, and exposed to such enormous pressure, the inlet has been divided into two parts by a cast-iron cutwater.

Against the internal face of the dam is a tower, containing three vertical chambers, two of which, corresponding to the inlets of the waterways, receive the rods of the sluice doors. The central shaft forms the well of a staircase and communicates with the side shafts by a small passage at each of the floors into which the total height is divided, thus facilitating the examination of the rods and their guides. Three loopholes are placed at each floor to give light to the interior. The lower part of the tower rests on a square back of masonry pierced by two arched inlets, forming a prolongation in front of the waterways, which can be closed with horizontal timbers, and allow of a free passage to the river through one outlet while the other is being repaired.

The sluice doors are formed of five sheets of wrought iron riveted together, their total thickness being 1·7 inch. The sliding surfaces are of gun metal. The vertical force necessary to raise the doors when the reservoir is full is estimated at 8·5 tons. To overcome such a resistance would require gearing; but on the right slope, at a distance of 780 yards, and 197 feet above the top of the dam, a spring was found, the water from which is collected in a tank and conveyed to a pair of cast-iron hydraulic cylinders, lined inside with brass, and resting upon a strong framing of cast iron, supported by four hollow columns, two of which admit while two discharge the water. The cylinders have an internal diameter of 19·7 inches each, which with a head of water of 197 feet give an effective pressure of 11·4 tons; and as the resistance to be overcome is only 8·5 tons, there is an excess of force of nearly 3 tons.

The dimensions of the orifices of induction and eduction have been calculated for a maximum speed of 0·079 inch per second, which may be diminished at will, resulting in a diameter being given to them of about 0·4 inch.

The main body of the structure is ordinary rubble masonry, the stone being procured in the excavation of the waste weir. The ashlar facings are hard Berroquena granite, similar to that used in Madrid. The hydraulic mortar is composed of 8 parts of sand, 4 of lime, and 1 of cement of Zumaya. The pointing is done with cement alone.

The most important auxiliary work in connection with the foundations was the diversion of the stream and the construction of a small auxiliary dam 164 feet up-stream, from which a bye-wash runs along the left bank for a distance of 500 feet. The stream at the site selected for the auxiliary dam is contracted; alluvium, 16 to 20 feet thick, had to be excavated, so as to plant the foundation on the bare rock, and the water was removed by pumping. The foundation was successfully got in, without interruption from freshets.

The bye-wash has a width of 8·2 feet, a depth of 6·5 feet, and a fall of 1 in 200, dimensions which will allow the river a free course, except during the prevalence of floods. This channel, the diversion dam, and other preliminary works, were completed at the end of the year 1869. The foundation of the great dam itself was commenced in the following spring. In laying bare the rock, a layer of alluvium, in some places 23 feet thick, had to be removed.

At the time the report was written the dam had reached a height of 103·3 feet.

Among the auxiliary works is a self-acting inclined plane, with double track for lowering materials.

The estimated cost of the work at the exchange of 50*d.* is given below:—

	£.
Expropriation	2,164
Diversion dam and bye-wash	4,442
Masonry of the dam	49,260
Sluices and apparatus	953
Bridge across the waste weir	1,030
Stores, workshops, and house	1,555
Other accessories	7,306
Total	66,710

The St. Etienne Waterworks. By M. DE MONTGOLFIER.

(Annales des Ponts et Chaussées, Feb. 1875, pp. 99–206, 3 pl.)

The town of St. Etienne formerly derived its water supply from the river Furens, on which it is situated, but the population of thirty thousand having been trebled between 1830 and 1852, and the river having become polluted by manufactories, MM. Graeff and Conte-Grandchamp submitted a scheme for supplying a population of one hundred thousand, which was sanctioned in 1859. They proposed to utilise the springs and streams of the upper portion of the valley of the Furens, and to construct collecting drains, an aqueduct, a reservoir, and a complete system of mains and service reservoirs. The works were completed between 1859 and 1866, at a cost of nearly £200,000, though, in 1863, water began to be supplied by the old service pipes.

The principal aqueduct, which intercepts twenty-five streams, commences 3,903 feet above sea-level, and discharges into the service reservoir du Rey at 2,050 feet, the total length being 10·8 miles. It is constructed throughout of masonry in cement, and has four different cross-sections. No. 1 has a flat invert, vertical side walls, and an elliptical arch, and is 1·2 foot wide by 1·6 foot high. Nos. 2, 3, and 4 are egg-shaped, their respective heights being 3 feet, 3·7 feet, and 5 feet, and their breadths 2 feet, 2·3 feet, and 2·6 feet. A length of 362 yards being in tunnel, the height of that portion has been increased to 5·6 feet. The entire aqueduct is covered by a 4-feet bank of earth. In the rapid falls the invert has been formed in steps. There are manholes at every 220 yards, and at all the junctions, falls, overflows, &c.

To collect the water of the springs, trenches, lined with masonry, were sunk to the rock, and drain pipes of earthenware and concrete, with open joints, and covered with stones, were laid in them to convey the water into water-tight collecting drains. The stones were covered with clay, sprinkled with milk of lime, to prevent the infiltration of surface water. The yield from the springs varies from 14 to 100 gallons, and the average consumption in St. Etienne is 33 gallons per second, or 2,860,000 gallons per twenty-four hours, which quantity the springs occasionally fail to supply.

The town is divided into a high-level and a low-level district, the former of which is supplied with water at high pressure from the reservoir du Rey containing 1,540,000 gallons. The principal main, 20 inches in diameter, branches into opposite directions to supply an east and a west reservoir; the maximum pressure being 233 feet. A second main, 10 inches in diameter, diverges out of the first near the reservoir du Rey, and rejoins it in the east quarter, owing to which arrangement the high-pressure system is never interrupted even for repairs. The low-level district is supplied from an old service reservoir, formerly filled from the river, but

now connected with the high-pressure main. It feeds a 12-inch pipe, which, in order to insure constant service, is connected by cisterns with the high-pressure mains at four places.

The diameter of the service pipes has been kept down to a minimum by the adoption of these cisterns, as an eventual increase in the consumption can be readily met by laying down an additional main from one of the existing cisterns, or by constructing a new cistern and main in connection therewith. The service mains are calculated to deliver 4,400,000 gallons every twenty-four hours at a pressure of 82 to 98 feet. The four service reservoirs contain collectively 3,500,000 gallons. The Paper gives full details of the cost of the pipe lines, and descriptions of the valves and hydrants employed in the works, of the fountains with spring taps that supply the inhabitants, and of the hydrants provided for extinguishing fires and watering the streets.

The reservoir of the Valley d'Enfer, which serves to guard the town against inundation, to supplement the deficient yield of the springs, and to accelerate the flow of the Furens in dry weather, has been formed by carrying a stone dam, exceeding 170 feet in height, across the valley. Its supply is regulated by a weir across the bed of the river, 1,859 yards above the dam, provided with ten sluices, each 5 feet wide by 8·2 feet high, constructed of a cast-iron plate, worked by windlasses, and fitted with gearing, to enable one man to move them. Five of these admit water into the reservoir, and five communicate with a canal alongside it, which rejoins the river lower down. The reservoir discharges into two tunnels, driven one above the other, through a hill into a neighbouring valley. The lower tunnel contains three cast-iron pipes, laid for a length of 36 feet in massive masonry, two of which, 16 inches in diameter, and furnished with regulating valves, discharge into a well, from whence the water can be directed either into the aqueduct for the supply of the town, or into the river. The third pipe, 8·5 inches in diameter, is always open for removing any deposit of water in the reservoir and for furnishing a constant supply to the manufactories. This tunnel is 202 yards long, has a fall of 1 in 1,000, and, with the exception of 55 yards through granite, is cut through schist, which from its loose character required expensive timbering.

The upper tunnel, 6·5 feet high, 5 feet wide, and 71 yards long, is driven in the same direction as the lower one, through rock, 146 feet above the bottom of the reservoir, and 18 feet below high-water level. It is closed by an iron sluice, and communicates with the canal, into which, at the termination of a flood, the water which has been impounded in the reservoir is gradually discharged. The total capacity of the reservoir is 352,000,000 gallons, of which 264,000,000 gallons are available for the supply of the town and the manufactories, the remainder being available for the storage of floods. The catchment basin of the Furens above the reservoir comprises 6,175 acres, the average rainfall being 33·4 inches, and the yield per annum 4,675,000,000 gallons, of which quantity

only 65 per cent., or 3,080,000,000 gallons, can be impounded. After deducting the town supply of 33 gallons per second, there remains a quantity equal to 66 gallons per second for the factories, which is amply sufficient.

The dam across the valley, constructed entirely of rubble masonry, varies in thickness from 9·8 feet at the top to 110 feet at the bottom, and is 170 feet high on the up-stream and 183·7 feet on the down-stream side. On the upper side there are two footings projecting 4 feet each, and one 8 feet, their respective heights above the bottom of the valley being 6·7 feet, 16·4 feet, and 154 feet. The lower face of the dam has only one set-off of 14 feet at 154 feet below the top. The cross section has been so designed that the pressure shall be nearly constant on all parts, and in no place exceed 93 lbs. per square inch. The centre line of the road-way on the top is an arc of a circle of 828-feet radius, with its convex side towards the water. The large quantity of masonry required for this dam, amounting in all to 52,000 cubic yards, involved a special organisation of plant and works, the details of which are fully described in the Paper.

The upper and lower tunnels, the regulating weir, and the diverting canal were completed before the dam was commenced. The latter is founded on compact granite, excavated to a depth of 3·3 feet, the masonry being executed in courses 5 feet high, of which the slopes were always carried up in advance of the hearting. The stones, measuring from 1·5 to 2 cubic yards, were bedded in mortar, the interstices being filled in with small stones. The fissures in the rock and dam were grouted with cement, the upper slope of the latter being similarly treated, with the result that but few insignificant leaks have been discovered in the valley below the dam, and a slight moisture on the down-stream side of the masonry. The construction occupied four summers, an average of 104·5 cubic yards being executed each working day.

The following is a summary of the cost of the reservoir :—

	£.
Regulating weir	1,440
Diverting canal	14,000
Outlet tunnels, lower	4,080
„ „ upper	720
Great dam	36,080
Land	7,280
Total	63,600

The following is the entire cost of the works :—

	£.
Purchase of land (543 acres) for impounding the springs and for the principal aqueduct	30,000
Construction of the aqueduct	43,200
Collection of the springs	14,000
Service-reservoirs, capacity 20,928 cub. yds.	11,200
Carried forward	98,400

	£.
Brought forward . . .	98,400
Pipes in the town, 71,084 yds. in length, hydrants, stand-pipes, &c.	25,600
Reservoirs of the Valley d'Enfer, including land	63,600
Watch-houses and various expenses	4,400
	192,000
Deduct subvention from the State	24,400
	167,600
The total cost of the works to the town, increased by laying additional pipes during the past two years and putting hydrants in all the streets, has been	180,000

This outlay is small, considering that the supply amounts to 2,869,506 gallons per day, or about 28·6 gallons per head.

The revenue from domestic and trade supplies amounts to £6,000 per annum, and the land purchased for the springs yields £600, making the total annual receipts £6,600.

The annual cost of maintenance and superintendence amounts to £1,440, whereby the net revenue is reduced to £5,160, or about 2½ per cent. on the capital.

The demand for water is daily increasing, and the second reservoir will soon be required, when the supply will be increased by nearly 4,000,000 gallons per diem, the additional revenue from which is expected to make the total net receipts equivalent to 5 per cent. on the outlay.

Great credit is due to the administration for so courageously undertaking the works described, which have furnished an abundant supply of pure and wholesome water, facilitated the development of industry, assured the health of the inhabitants, removed the epidemics that formerly decimated the population, and, at the same time, preserved the town from the danger of inundation.

C. H. B.

The Aqueduct of Narni, and its Works of Restoration.

By B. Fabri.

(Il Politecnico, April 1875, pp. 185–195.)

This aqueduct, said to have been constructed by Nerva, and known as the Formina, takes its source in the ridge of chalk hills extending from the south of Narni, 30 miles north of Rome, towards La Sabina. In a winding course of about 8 miles it crosses several deep ravines, passes through two hills, and over a massive bridge paved in mosaic pebble-work, which connects the two subterraneous passages. It is generally paved, walled, and vaulted in masonry, the internal section being 2 feet wide by 6·5 feet high.

The offtake, situated at a kind of natural collecting ground, is a

walled basin, into which the water from the hills and from the wide valley of the Umbra is collected by infiltration, and through various small masonry drains, many of which were obstructed or completely dry. An attempt to clear and deepen this offtake not being successful, it was resolved to make two large catchwater channels, one of which, 16·4 feet deep, followed the direction of the fosse known as the Capo d'Acqua; while the other, 26·25 feet deep, was laid from the basin of reception towards the foot of the watershed of Monte San Urbano.

In a report to the municipality the Author fully describes the works necessary for the control and management of the water thus obtained for the supply of the Formina, and adds some recommendations as to the mode of purifying the water. An analysis of the calcareous sediment, and sometimes calcareous concretions in the aqueduct, showed that—1st, the bicarbonate of lime was deposited in greater quantity under greater velocities, and very little in stagnant water; 2nd, that this deposition hardly ever took place except when the water was in contact with the external air; 3rd, that the deposit increased under higher temperatures; 4th, that it increased with the distance from its source. The latter conclusion is borne out by corresponding facts on the Aqueducts of Felice, Gallicano, and Marcia. The water was free from sulphates, and comparatively free from organic matter; and containing chlorides of a rather advantageous nature, its purification from calcareous sediment was well worth the expense.

It was determined to substitute iron pipes for those of lead, to keep them clear of deposit by frequent scouring and cleansing, and to make a depositing basin in which the calcareous salts could be precipitated. The latter was made at the city wall; it was 16·4 feet long and 6·5 feet by 2 feet in section, the water entering above at one end, and passing out below at the other, after having been filtered through three layers of the following material:—1, large breccia; 2, gravel; 3, vegetable carbon. Owing to these arrangements, it is now always limpid, and steady and constant in supply. There are no deposits or incrustations in the iron pipes; thus proving the efficiency of the filtering arrangements.

J.

Irrigation of the Plain of l'Habra. By Léon Pochet.

(Annales des Ponts et Chaussées, April 1875, pp. 261–389, 3 pl.)

Algeria may be divided into three geographical sections. That known as Le Tell embraces the country bordering on the Mediterranean, the rivers of which drain into that sea. The higher plateaux, ranging in elevation from 2,000 feet to 4,000 feet, shed their water into the interior lakes; while the third section, the Desert, composed of many varieties of soil, of which sand is the commonest, contains no permanent watercourses.

The plain of l'Habra is situated in the first of these districts, and in winter is subject to floods, and in summer to drought. The entire area of the basin amounts to 2,470,000 acres, over which for a period of thirty-two years the annual average rainfall did not amount to more than 15 inches. It is calculated that in this district only $\frac{1}{37}$ of the rainfall appears in the streams; whereas in France the annual volume carried away by the watercourses is equal to from $\frac{1}{4}$ to $\frac{1}{2}$ of the rainfall. With so enormous a loss of water, timber in l'Habra is necessarily scarce, the ground is bare and uncultivated, and the land tilled during summer does not exceed 15,000 acres, or $\frac{1}{160}$ part of the district. It will be seen from this that the water question is one of vital importance for colonisation in Algeria; and as the natural supply varies from 660 gallons per second in winter to 110 gallons per second in summer, while during floods in winter it rises as high as 154,000 gallons per second, it was indispensable to erect a storage reservoir, on the principle of those in Spain, capable of holding 6,600,000,000 gallons.

The construction of so large a work was conceded by the Government to a private company, under the conditions that of the 89,000 acres placed at their disposal, 29,000 were to be used in grants to Arab tribes and colonists, and 60,000 for the construction of the reservoir and irrigation, each portion to receive its due share of water, which was to be attached to, and be inalienable from, the soil.

The first project for the dam of l'Habra was that of an earthen bank; but while preparations were being made for its erection, similar structures on the Sig at Tabia and on the Tlélat were ruptured by floods, and it was resolved to adopt masonry. The height of the wall was fixed at 116·7 feet above the bottom of the valley, and the height of water at 111·5 feet, leaving 5·2 feet as the height of the crest above the water-level. The length of the crest is 1,214 feet, which, with an overflow of 394 feet, gives a total length of 1,608 feet. The right bank rises abruptly; the left slope, on the other hand, is more gentle, and the profile of the dam was calculated from the formulæ established by M. Delocre.[1] It may be said to consist of three superposed trapezes and a rectangle, of the following dimensions, beginning at the top:—

	Height.	Top width.	Bottom width.
Rectangle	19·7 feet	14·1 feet	14·1 feet
First trapeze	31·5 „	14·1 „	32·8 „
Second trapeze	32·8 „	32·8 „	62·7 „
Third trapeze	26·3 „	62·7 „	88 „
Total . .	110·3 „		

The sides of the rectangle are vertical. In the first trapeze the batter of the outside wall is 54·3 per cent., and of the inside 5 per cent. In the second trapeze, the outside batter is

[1] Annales des Ponts et Chaussées, vol. xii., 1866, pp. 212–272.

6·3 per cent., and the inside 2·8 per cent. In the third, the respective figures are 6·3 and 3·5 per cent. The foundation of this wall is of masonry 6·6 feet thick, the outside face having a berm of the same dimensions, and it rests upon a bed of concrete 13 feet thick, filled in on the irregularities of the rock, so as to form a level for the springing of the arch.

In consequence of the large deposits of sand, calculated at 325,000 cubic yards per annum, and actually amounting during the five years of operation to 1,222,000 cubic yards, the dam is provided with two scouring outlets in the centre of the valley, 117 feet apart, their sills being 9·8 feet from the bottom. There are, in addition, four cast-iron pipes, 31·5 inches in diameter, in pairs on each side, for the supply of the irrigation canals. The area of entry of each scouring sluice is 24·1 square feet, or 48·2 square feet total for 1,950,000 cubic yards of sand, as against an area of 48·5 square feet for 291,200 cubic yards of sand for the well-known dam of Alicante, in Spain. These quantities represent a scouring every fourth year. It remains to be seen whether the greater amount of time required for the operations at l'Habra will be inconvenient.

Each sluice-gate is composed of wrought iron 3·2 inches thick, and is worked from the top by wheels and pinions, turned by hand. Experience proves the calculations for this machinery to have been somewhat faulty. The pressure upon the sluices is enormous, amounting sometimes to 59 tons, and it requires the strenuous efforts of four men to raise them; in view of which result, it is proposed to substitute hydraulic pressure for manual force. The working of two outlets for irrigation, devised in order to divide the water in due proportion between the company and the colonists, was found impracticable, and that on the right bank was alone retained. The two cast-iron pipes which it contains are laid in the masonry, provided with valves outside, and calculated to supply the required 660 gallons per second, even when the water has fallen to 19·3 feet above the valley, and 19·7 inches above the centre of the pipe.

The building of the dam was commenced in November 1865, and finished in August 1871, the material employed being rubble in hydraulic mortar, the latter composed of 2 parts of sand and 1 part of hydraulic lime from Oued-Fergoug. In the winter of 1871–72, nine months before the final completion, the water was allowed to rise in the reservoir. When it had attained a height of 33 feet to 40 feet the dam began to sweat, which continuing as the water rose, gave it the appearance of an immense filter; this is readily accounted for by the very porous nature of the grit that had been used in its construction.

The quantity of water considered necessary for the irrigation of 1 acre during the five irrigation months is 470 gallons a day, and is conducted by Spaniards, who understand the management of irrigation works, upon the following system:—The land is divided into uniform sections, each of which is provided with a secondary

canal, receiving its water from a primary canal, which again is supplied direct from the main canal. The entire amount of water available is distributed by measuring sluices, in proportion to the sections they irrigate, amongst the primary canals, and through these among the secondary canals by rotation, and each proprietor receives the water from the secondary canal for a certain time, calculated for the area he has to irrigate, after the lapse of which the guard shuts it off, and turns it into the next. The point of importance to be observed in this arrangement is the size of the secondary canals. At Saint-Denis du Sig each secondary canal received 3·3 gallons per second for the zone of garden ground, and 5·5 to 6·6 gallons for ordinary ground; but as this supply is now confessed to be not only too small, but also too slow, an average supply of 22 gallons per second was adopted in l'Habra.

The total volume of water disposable is calculated as follows:—

		Gallons.
Total storage room in the reservoir		6,600,000,000
Water which lies below the outlet pipes	198,000,000	
Evaporation during 5 months over an area of 200 hectares	352,000,000	
Loss by filtration	440,000,000	
		990,000,000
		5,610,000,000

This corresponds to a discharge during the five irrigating months of 440 gallons per second, or, allowing a volume of 220 gallons for the average discharge of the reservoir, a total amount of 660 gallons per second. The division of the waters in the primary canals is effected by discharge over a thin plate, the width of which is exactly proportionate to the area of ground which the secondary canal has to supply. Each partition sluice is composed of a rectangular chamber, in the sides of which there are openings, and through these the water discharges over the plate. This method, if not mathematically, is practically exact, and is so accepted by the irrigators.

The total length of the primary canals in the l'Habra district is as follows:—

	Yards.
East canal and branches.	20,560
Centre-eastern canal	15,912
Branches of ditto	16,514
Western canal	25,710
Centre-western canal	4,430
Total . . .	83,126

The secondary system of canals will be completed as the ground is put under cultivation. It is calculated that a length of 437,450

yards will be ultimately required, and the cost is estimated as follows:—

	£.
437,450 yards of canal at about 3*d*. a yard .	5,600
1,800 sluices at 56*s*.	5,040
	10,640

The practical result of the works undertaken remains yet to be proved; many years must elapse before the land can be put into thorough cultivation, and a large population must be brought into the valley.

G. H.

The St. Louis Canal and the Mouths of the Rhone.

By M. Dornès.

(Mémoires de la Société des Ingénieurs Civils, No. 4, 1874, pp. 740–746.)

Before the construction of the Lyons and Marseilles railway the Rhone formed the chief highway between the Mediterranean and the centres of industry in the south of France; and at that time, notwithstanding the continual changes in the bed of the river and of the bar at the mouth, the navigation was skilfully conducted, and with but few mishaps. But when the navigation lost its importance, the service was less careful, and accidents so multiplied that, in the year 1852, it was decided to improve the river, which at this period reached the sea through a number of branches, those to the right and left of the principal one being termed *graus*. It was determined to close the whole of these *graus*. The river being thus narrowed 2 to 2½ miles at mean water-level, and confined to a single channel by guide banks, would be enabled to scour away the bar, while it was assumed that the well-known littoral current of the Mediterranean would at once carry off the sands so removed.

The immediate effect of the works was, however, simply the displacement of the bar seawards. In 1856 it had advanced about 4,000 feet into the sea, but the littoral current failed to carry off the sand brought down by the river. The navigation becoming still more dangerous, it was determined to verify the existence of this littoral current, upon which the whole project was based, and a few experiments sufficed to prove that it existed only at the surface, there being still water at a depth of 6·5 feet. This phenomenon was accounted for by the water of the Rhone floating on the heavier sea water, and being driven by the prevailing winds from the east and south-east. The mud and sand held in suspension were carried along the shores of the Mediterranean as far as the Port of Cette. It was then decided to abandon the works at the mouth of the river, and to turn the flank of the bar, while connecting the Rhone with the Mediterranean by a salt-water canal 3,716 yards long, 206 feet wide at low-water line, and 19·6 feet

deep. This canal has now been completed from its commencement in the Bay of Repos to its termination in a basin of about 30 acres adjoining the Rhone, at a cost, inclusive of the lock, which is 505 feet long by 72 feet wide, and of the quays on the Rhone, of not less than £700,000.

It was feared by some engineers that the sand carried by the prevailing winds from the adjacent uncultivated plains would gradually choke the canal and port; but the natural vegetation retains the sand, and there is no ground for alarm on this head. A more real danger might arise from the silting-up of the Gulf of Foz, and the canal entrance, by the materials brought down by the Rhone, which, passing over the bar, form at first islands called *theys*, and ultimately, by their union, an extension of the mainland, at the rate of from 260 to 300 feet seawards in a year. This encroachment is not surprising if it be remembered that the Tower of St. Louis, now 5 miles inland, was built in the year 1737 on the sea beach, and that the Rhone brings down no less than 2,600 cubic yards of sand per hour.

The possible danger from silting-up has been strongly urged by M. Germain, though, in the Author's opinion, with much exaggeration, since upon finding a difference of 3·28 feet in the soundings taken in the years 1841 and 1872, M. Germain concluded that a general silting-up was in progress which could not fail ultimately to close the Bay of Foz and the entrance to the canal. The Author contends that the silting-up occurred during the eleven years immediately following the year 1841, and before the *graus* discharging directly into the Bay of Foz had been closed. In confirmation of this opinion, he states that since the commencement of the canal works in 1865 charts have been prepared every year, and as no diminution in the depth of the bay has been found, the fear of the canal entrance being silted-up is groundless. It is admitted, however, that the continual advance of the land seawards may eventually close the entrance to the Gulf of Foz, and that this tendency might, perhaps, best be checked by reopening one or more of the *graus* on the right bank of the river which were closed in 1852.

The usefulness of the canal cannot be fully developed until the course of the river itself is improved. Although much has been done, it would cost an additional £1,200,000 to give to the Upper Rhone alone a depth of 4 feet at low water. Between Arles and the sea, the bed of the Lower Rhone, which is here very wide, has been improved by two parallel banks of rubble carried a certain height above low water, and forming a canal 390 yards to 520 yards broad. These guide banks are tied to the shore by mounds of rubble at right angles to the current. During floods the whole of these works are submerged, the cross banks check the current and cause eddies, and lead to the silting-up of the space between the artificial submerged banks and the real banks of the river, at the rate occasionally of from 16 feet to 20 feet in depth during a single flood. Upon the subsidence of the waters,

willows are planted which grow rapidly: they consolidate the ground by their roots, and not only protect the land which has already been reclaimed, but facilitate further deposits. It is not rare to see these artificial banks more than 3·28 feet above the tops of banks which served to form them. In the channel to which the main current has been confined by the guide banks, the river shapes its own bed in the alluvial ground, and a depth of from 16 feet to 20 feet is thus secured throughout the whole length between Arles and St. Louis, except at one point, where the required depth can be readily obtained by blasting.

B. B.

A Self-acting Shutter for Canals. By BALDASSARE NICORINI.

(Il Politecnico, April 1875, pp. 201–207.)

The object of this shutter, or weir under which the water flows, is to maintain automatically a constant head of water in a channel, whatever its discharge may be. It is a flat shutter of wood, closing the whole width and depth of the channel, and turning on its upper edge as an axis (probably on horizontal metal trunnions), which is set at the constant depth desired. An increased pressure of water forces the shutter outward, and increases the section of opening between its lower edge and the sill on the bed of the channel. Permanently fixed near the middle of the shutter is a metal curve, on which a heavy ball is placed, the weight of which tends to keep the shutter closed, or to diminish the section of opening.

The equation to the curve necessary to maintain a constant level in the water above the shutter, is determined by considering the sum of the moments of the three forces actuating the system to be in equilibrium, viz.: the weight of the ball, the weight of the shutter, and the pressure of the water. Their moments are taken with reference to the axis of rotation.

Let α = the angle made with the vertical by the shutter when open.
r = the height of the shutter.
l = the width of the shutter and also of the channel.
w and u, the weight and leverage of the ball.
w_1 and u_1, the weight and leverage of the shutter.
P and U, the pressure and leverage of the water.
a and b, the co-ordinates of the centre of gravity of the shutter.
x and y, the co-ordinates of the point of contact of the ball with the metal curve.

The respective moments of the three forces are then—

$$w\,u = \mathrm{W}\,(x \sin \alpha + y \cos \alpha)$$
$$w_1\,u_1 = \mathrm{W}_1\,(a \sin \alpha + b \cos \alpha)$$
$$\mathrm{P\,U} = \tfrac{1}{2}\,l\,r^2 \cos \alpha \times \frac{2\,r}{3} = \frac{r^3\,l}{3} \cos \alpha\,;$$

and putting P U = K cos a, the sum of the moments is

$$w\,(x \sin a + y \cos a) + w_1\,(a \sin a + b \cos a) - \mathrm{K} \cos a = 0,$$

assuming that the tangent described by the point of contact of the sphere is horizontal: and calling $d\,s$ the differential of a portion of the length of curve,

$$\sin a = \frac{d\,x}{d\,s} \text{ and } \cos a = \frac{d\,y}{d\,s};$$

and substituting them in the equation of moments,

$$w\,(x\,d\,x + y\,d\,y) + w_1\,(a\,d\,x + b\,d\,y) - \mathrm{K}\,d\,y = 0;$$

and integrating this,

$$\frac{w}{2}\,(x^2 + y^2) + w_1\,(a\,x + b\,y) - \mathrm{K}\,y = \mathrm{C},$$

and putting $m = \dfrac{2\,w_1\,a}{w}$ and $n = \dfrac{2\,w_1\,b - 2\,\kappa}{w}$

$$x^2 + y^2 + m\,x + n\,y = \mathrm{C},$$

and completing the quadratic

$$\left(x + \frac{m}{2}\right)^2 + \left(y + \frac{n}{2}\right)^2 = \mathrm{C} + \frac{m^2}{4} + \frac{n^2}{4}.$$

Of which the values $-\dfrac{m}{2}$ and $-\dfrac{n}{2}$ are the co-ordinates of the centre of the curve, and the square root of the second member is the radius. Observing then that the ball is always at a point at the extremity of a vertical radius, it is evident that any length of radius will satisfy the conditions of the case. Hence the same result may be obtained by removing the metal curve altogether, and fixing the ball at the actual centre from which the arc or curve is described.

A figure accompanying the original Paper shows the ball, attached by a straight arm to the upper edge of the shutter; an additional short piece of shutter is also introduced above the axis of rotation, to prevent occasional loss of water, and to stop the shutter from turning over when in an extreme position.

L. D'A. J.

On the Cross Section of Drains. By A. Frühling.

(Zeitschrift des Arch. und Ing. Vereins, Hannover, xxi, cols. 39–51.)

In designing a system of drainage for a town, one of the first points to be fixed is the cross section of the drains. For this purpose the maximum discharge at the upper end has to be ascer-

tained, and the rate at which this discharge increases from the upper end to the outlet, this rate depending on the character and configuration of the drainage area. It is also necessary to know the water-level at the outlet, and the highest level to which the water may rise at the upper end without impeding the drainage of the area communicating with that end. The difference between these two levels gives the 'serviceable fall,' and from the above data the cross section of the drain must be determined. Where, however, the inclination is great or the discharge small, this area must for practical reasons be many times larger than would be given by theory. Thus pipe drains from streets should not be less than 8 inches in diameter, to prevent stoppages; and sewers, to be accessible, cannot be of a less height than 3·94 feet. For large towns, however, the question is of the highest importance, especially where the discharge is great, the inclination small, and the drains are carried deep underground for considerable distances. Should the dimensions adopted be too large the cost of construction will be excessive, and in dry weather the stream will be too shallow to prevent accumulations of rubbish. Should they be too small, the drain may be unable to carry off the waters in heavy rains, and the streets and cellars will in consequence be flooded.

The first point to settle is the fall, which mainly depends on the two levels mentioned above. Other considerations come in, such as the depth of the invert below the surface, a drain at a higher level, though of larger dimensions, being sometimes more economical than a deeper one, from the saving in excavation; on the other hand, the slope must not be so small as to produce an accumulation of rubbish. These conditions will not be much altered where the water, instead of flowing through the drain, is drawn from the lower end by pumps.

The network of drains for the district must be laid out on a single plan, and the amount of water which each drain will have to convey must be ascertained from the most recent reports on the population of the place, and from observations on specially high floods. The size of the various pipe drains, where they are supposed to be completely filled, as in heavy floods, may be ascertained by Weisbach's formula, which gives

$$\text{Discharge} = \frac{\pi}{4}\sqrt{\frac{d^5}{G} \times \frac{2\,g\,h}{l}},$$

where h is the 'loss of head,' or difference of the water-level in two shafts at each end of a drain, length l, diameter d, and G is a quantity given by Weisbach as equal to

$$0\cdot01439 + \frac{0\cdot0094711}{\sqrt{\text{velocity}}}.$$

The value of d, the diameter, may be found from the above equation by first taking an approximate value of d in order to find

v and G, and afterwards calculating d from the values so found. The process, however, being tedious, a table of values is given to facilitate the calculation. Where the drain is large the resistances given by the formula will be somewhat above those realised in practice. This is probably due to Weisbach's experiments having been made only on pipes of moderate size, to the influence of bends, &c., and to the varying friction against the inner surface of the pipe. The influence of the last is so great, that the resistance in a wooden pipe about 4 inches in diameter is given by Weisbach as $1\frac{3}{4}$ of that in a similar pipe of metal.

Culverts of masonry are next considered, and assumed to be always of the egg-shaped section. The advantages of this shape, from the greater depth and velocity of current it produces, are well known; and to this may be added that the line of pressures conforms very closely to this section, and hence the walls may be made thinner than with other shapes. Taking Eytelwein's formula for the flow of water in pipes—

$$v = \sqrt{\frac{f}{G\,l\,p} \times 2\,g\,h},$$

where v is the mean velocity, h the difference in level at any two points, l the length between them, p the 'wet perimeter,' and f the 'immersed area.' Since the discharge is equal to the immersed area multiplied by the velocity,

$$Q = f\sqrt{\frac{2\,g}{G}} \times \sqrt{\frac{f}{p} \times \frac{h}{l}}.$$

The expression $\sqrt{\frac{2\,g}{G}}$ is not constant, but varies (according to Weisbach) with the velocity. The variation for ordinary velocities is so small, however, that it is safe in practice to take it always as equal to 49. In applying the formula, Q, h, and l are supposed to be given, and also H the depth of water required. It is obvious, however, that the dimensions of the cross section cannot be fixed thus, but must be found by experiment. To do this for every different discharge would be tedious, and to lighten the labour a table is given of the values of $49\,f \times \sqrt{\frac{f}{p}}$ for culverts varying in height from 3·94 feet to 6·56 feet, and at various depths of water. As this expression is equal to $\frac{Q}{\sqrt{\frac{h}{l}}}$, the process will be:

Find the value of $\frac{Q}{\sqrt{\frac{h}{l}}}$ (all these three quantities being given); find the place in the table where the nearest value to this is com-

bined with the depth required; and the figure given at the head of the column will show the height of the culvert best adapted for carrying off the given quantity of water, with the depth required. The form of the egg-shaped section being known, the immersed section and wet perimeter for any given depth can be found by trigonometry. The maximum discharge is (as in the case of a circle) when the culvert is about nineteen-twentieths full, not when it is quite full, the increase of area being more than balanced by the increase of surface friction.

To find the velocity for various discharges, a table is given of the area of the immersed section for various depths, and for heights of culvert from 3·94 feet to 6·56 feet. By means of these tables (and of similar ones for round pipes) the problems which arise in designing a system of drainage can generally be solved without difficulty. Several examples of such problems are given. In the first, a pipe drain of given length and fall has to convey a certain quantity of water through the first portion of its length, and another larger quantity through the remainder: the alteration of section at the point where the second supply comes in is determined. In the second example a pipe drain falls into a culvert, and, in order that it may never throw into the culvert more than the latter can carry off, an overflow drain is to be fixed in a well at some point on the pipe drain, so as to carry off in the highest floods a certain fixed quantity of water: the diameter of this overflow pipe, and its height above the drain pipe, are determined. It appears that the diameter of the drain pipe may be reduced after passing such an overflow pipe; but in long drains this is not desirable. The other examples are only designed to show the general mode of using the tables.

W. R. B.

Pile-driving Apparatus. By Herr Weber.

(Protokolle des Sächsischen Ingenieur Vereins, 6 Dec. 1874, pp. 20–24.)

Nearly all the pile-driving machines at present in use are adapted for operating on only one pile at a time; it is the object of this machine to place several rams under the control of a single steam-engine. The apparatus by which this is effected may be divided into three parts—the engine, the power-distributor, and the ropes or chains which lift the monkey. Any of these may be separated and fixed at varying distances and different levels. Any engine, with which driving bands can be employed, may be used to provide the motive power, the bands imparting it to a system of ropes or chains by which the rams themselves are actuated.

A light timber frame carries the power-distributor, which consists chiefly of a pulley, rotated by the driving band of the engine, and imparting motion to a poppet head running backwards and

forwards on two timber bearers. An endless chain or rope passing over this poppet head communicates, at the foot of the scaffolding erected on the spot where the pile is to be driven, with the machinery for lifting the monkey. The endless rope can be slackened or tightened by a lever, and movable discs or pulleys, over which it passes, enable it to be adjusted in any direction required by the position of the pile. The third part of this machine consists of the ordinary monkey, lifting ropes, windlass and scaffolding; but a special arrangement is provided by which the drum can always be rotated, whatever position it may assume with respect to the power-distributor, whilst at the same time it is kept at right angles to the lifting rope, so as to prevent its slipping off.

This invention was used at Dresden on the Elbe, for fixing the piles of a quay wall 541·2 yards long. The engine and power-distributor were placed on a platform, fixed to two pontoons coupled together, while attached to them by long raking timbers, which served also as foot-bridges, was a raft 114·8 feet long by 13·1 feet broad, on which the three pile-drivers with their machinery were fixed. On two of these the monkey was raised and dropped between parallel guides, but in the third an iron pole was fixed on the head of the pile, the monkey working up and down it through a hole in the centre. The engine, power-distributor, and pile-drivers required one skilled attendant each, in addition to which six or eight labourers were variously employed.

Of the total number of piles driven, four hundred and fifty-nine were main piles, and one thousand six hundred and thirty-four intermediate piles; the former were from 9·8 to 16·4 feet long and $7\frac{1}{2}$ inches square, the latter being from 9·8 to 27·5 inches square and 13 feet long. The main piles had shoes of wrought iron, made in four pieces, and were driven from 5 to 7 feet into a bed of rough gravel and stones; the intermediate piles were merely shod with sheet iron, and put down to a depth of from 3·6 to 3·9 feet. The work occupied thirty-two days, during which time 120,000 blows were struck, by rams weighing each 8·07 cwt., with a fall of 9·84 feet, a height which proved most suitable. This averaged 1,580 blows for every cubic mètre of timber driven, or 242 for every square mètre of the wall itself. The monkey was lifted 65·6 feet every minute, or 13·11 inches per second, showing that the work done by each pile-driver was as follows:—8·07 cwt. $\times$ 65·6 feet = 59,299 foot-lbs. = 1·8 HP., or a total of 5·4 HP. for the three drivers.

The steam-engine had a cylinder 10·23 inches in diameter, with a stroke of 15·75 inches; the pressure of steam in the boilers was 3 atmospheres and the expansion $\frac{1}{3}$; the indicated HP. was 6·03, showing very little loss of power between the motor and the pile-drivers. The relation between the power at the windlass drums and the weight was as 1 to 19. The winding ropes, 0·6 inch in diameter, were of cotton, not hemp, and gave excellent results as regards friction; assuming the latter to be 9·25 lbs., the

tension was about equal to 47·6 + 9·25 = 56·85 lbs. The cost of every main pile driven was about 6*s.* 6*d.*, and of every intermediate pile 2*s.* 3*d.*, or equivalent to about 11·3*s.* per square yard of the wall. Had the pile-drivers been hand, instead of steam-driven, the work would have been increased 13 or 14 per cent., and have lasted fully fifty-five days. This apparatus is specially valuable on extensive works, when the frequent removal of the engine is not necessary.

H. T. M.

Concreting Dry Docks at Ellerbeck, near Kiel.

By H. Rechtern, Chief Engineer.

(Zeitschrift des Arch. und Ing. Vereins, Hannover, xx., cols. 497–509, 2 pl.)

The Marine Establishment, where these works were carried on, is situated opposite the town of Kiel, and, although many advantages were connected with the site, the construction of the jetties and docks was somewhat impeded by large and deep-lying masses of mud. The general features of the scheme comprise two wet docks connected with each other and with the harbour by canals, and four dry docks. One of the wet docks has a length of 947 feet, and a breadth of 720 feet; the other is about 721 feet square, the depth of both at low water being 33·8 feet. The level of the quays is about 1 foot above the highest points reached by the sea during the storm of the 12–13th of November, 1872; the length of the quays is 2,351 yards. The total amount of earth to be transported was nearly 4,000,000 cubic yards, which was deposited at the top of the Kiel Harbour, the so-called Horn, where the water was only 3 feet deep, the mud below it reaching a depth of from 35 to 50 feet. To prevent this mud from being forced into the harbour, through the weight of earth, a dam was constructed across that part; but it was found somewhat difficult to get a firm point from which to tip the wagons. A punt connected with the shore by strong beams was first tried, but the earth pressed the mud underneath it, the rails became uneven, and entire wagon-trains were in danger of being upset. Fortunately, only two were thus lost, and the scheme was abandoned in favour of a raft, the beams of which could be transferred from back to front as the dam proceeded.

The excavations for the docks and quays were all carried on simultaneously, when practicable, to a depth of 15 feet, the sheet piling was then driven, the required depth obtained by dredging, and the concrete foundation laid under water. The pumping station comprised a double set of boilers, engines, and pumps, one of the latter lifting 27 gallons a second, by which the water could be maintained at a level below datum of 20·6 feet. The second pump was only worked when repairs or great pressure of water required it, and this was found less expensive than draining all the

water to one point. The excavations being very long, it was not difficult for locomotives to drag the trains to the required height of 35 feet, although each train consisted of sixteen wagons, and each wagon contained 88 cubic feet of wet earth. The wagons were so constructed that the upper framing could be moved sideways on rollers, and then tipped; but, although they were theoretically correct, the axles, wheels, and other parts, being constructed for horse-work, were too weak, and had to be abandoned. In 1872 and 1873, 2,910 cubic yards of soil were removed daily; but in 1874, owing to the increased depth, the average daily amount did not exceed 2,340 cubic yards. In driving the piles, Nasmyth's steam pile-drivers, four of which were used, were found excellently fitted for the work. The length of the piles varied from 25·5 feet to 37 feet. They were 10·2 inches thick; the rams worked at the rate of fifty or sixty blows a minute, the fall of the monkey, the weight of which exceeded 2 tons, being 20 inches. The method by which the work is accelerated through the employment of a powerful jet of water, was not adopted, as a loosening of the soil and re-charging of springs might be the consequence. Two rams with endless chains of the Sissons and White pattern were also tried; but the top of the pile was generally smashed, and the sheet piling, in consequence of bad guidance, very loose. The line of the piles was fixed by two parallel horizontal beams laid with the thickness of a pile between them, and it was found advantageous to drive two piles side by side, fastened by strong iron hoops, the gain being due, it is supposed, to the increased rigidity, the vibration, which is a great source of loss of power, being thereby much diminished.

The materials composing the mortar for concrete, prepared beforehand, were mixed in the proportion of 3 of trass, 2 of lime, and 1 of sand, and thrown in. The trass, a kind of tuffstone, chiefly used for its cheapness, was in many respects superior to cement, and united the gravel and loose stones more firmly; but in small works, where mills would be an extra expense, and especially where quick setting is required, cement concrete is to be preferred. As it was difficult to maintain the exact proportions in mixing the trass, a rotator of a peculiar form had to be employed; while in making the cement concrete, cement and sand were ground in an upper mill, and stones and mortar in a lower one. Both mills turned out about 144 cubic yards in ten hours.

In using the trass concrete, care should be taken to create as little mud as possible, and especially to guard against the action of water before it is set. In the Kiel docks the concrete was laid from a raft in great masses and as rapidly as possible. Ten caissons or boxes containing about 1 cubic yard each were hung side by side from a floating raft constructed by Herr Bechering, of Essen, and all were sunk at the same moment. Subsequently the amount was increased to nearly 2 cubic yards per caisson, the increased weight producing, as had been expected, a greater coherence in the material. Winches for lowering the boxes were

attached to the raft, and, with their loads carefully adjusted to the draught of the gunboats that assisted in the work. Four men worked the crabs, the strain at the drum being taken at 2·5 cwt., the weight of the boxes and chains being 76·8 cwt. The only difficulty occurred when, through the boxes accidentally failing to open, they had to be raised again. By this means 523 cubic yards of concrete were lowered per day, the total quantity required being 49,010 cubic yards.

As soon as half the number of the boxes that stood in readiness were filled, and the surface of the concrete was well stamped in, the lowering was proceeded with, while the remainder of the boxes were filled; the thickness of the concrete varied from 5·2 to 6·5 feet; it was put down in two successive layers, the first consisting of three boxes, and the second of two. These rapid deposits, over a small area in one day, prevented the mud getting into the crevices, the boxes containing the second layer not being allowed to discharge their contents until they had actually touched the first layer. Very little concrete was carried away by the water, great care being observed to lower the first layer slowly, so that the air might have time to escape. If this precaution is neglected, the lime is readily washed away. Owing to the difficulty of dredging close to the piling, a dike of concrete was laid on the outside. H. T. M.

On the General Causes of the Destruction of Wooden Poles.

By M. Bourseul.

(Annales Télégraphiques, March—April, 1875, pp. 131–147.)

Under the influence of air and moisture wood changes superficially and takes a deeper colour; it oxidises or undergoes combustion, but the action is exceedingly slow. It is known that under water at great depths, and free from the action of air, wood may be preserved for centuries. For rapidity of change the simultaneous action of air and water is necessary. When the air is in excess—that is to say, when wood kept moist is exposed to air—the deterioration is termed 'dry rot.' If, on the contrary, water is in excess—that is to say, if the wood being very wet is acted on by the air, but without free access, as happens with poles near the surface of moist earth—the decomposition takes the name of 'wet rot.' The third cause of destruction is fermentation, or the complete metamorphosis of the nitrogenised substance. The question is whether any fluid injected into the pores of the wood will prevent fermentation and impede dry and wet rot. A pole injected with any fluid, if placed in earth which is rendered humid by calcareous matter, and divided by sand so as to admit the air, may be preserved from fermentation; but it will be destroyed with more or less rapidity by one or the other rot. On the other hand, if the wood becomes subject to putrid fermentation, it is rapidly disorganised,

and the third cause of destruction is combined with the others. This most frequently occurs with wood that has received no preparation. The residue of the two kinds of rot when examined are found to differ materially. Dry rot produces a brownish spot in the direction of the fibres of the wood, much narrower in the transverse direction. This spot penetrates gradually to the heart of the wood, the surface is loosened, and the mould, which is sometimes called 'black rot,' may be easily detached, and the wood looks as if slowly charred by fire. Although a pole thus affected may last some years, the 'white' rot acts with extreme rapidity, and the residue has no similarity to that of the dry rot. The tissue appears swollen by moisture; it remains compact, but is very easily cut, and then presents a smooth surface. When wood is attacked by wet rot, it develops a fungus of determinate character. With the pine and fir it is the *merulus destruens* or *lacrymans*, and appears at the part of the wood least exposed to the light. It is a dangerous enemy; and injected telegraph poles on the railway between Toulouse and Montauban, where the way approaches a lateral canal, have been rendered by it unfit for service in six months. When once a planted pole is attacked by *merulus*, its preservation becomes difficult. The best way is to remove the affected part, and by a covering of compact clay, to prevent access of air, which is essential to the vegetation of the fungus. It is therefore necessary when planting a pole to make the earth around it compact.

At the best, however, these remedies are but rough, and in order to preserve the pole permanently the surface of the wood should be completely isolated from air and water. For this purpose a hole is made round the pole in the shape of an inverted cone to a depth of about 20 inches. The hole is filled with béton or cement, and the block terminated above the level of the soil by an inclined surface, so as to allow the rain to run off. The joints near the wood should be trimmed with great care. Good results are also obtained by treating with tar-oil, or with mineral pitch or paint, and covering with a plate of zinc soldered at the joint, and luted above and below. A pole should never be planted in the hole where one has previously rotted, since it would be speedily destroyed by the germs left by its predecessor. Mineral pitch as a preservative has not had much success, because, in the Author's opinion, it has been unfairly treated. The wood should be strongly heated and the pitch applied hot in several thin layers, care being taken not to heat the pitch too long, as it then loses its essential oils, and is reduced to mere bitumen.

Carbonisation gives good results. By carrying the wood to a sufficiently high temperature, fermentable matter is coagulated and foreign organisms are destroyed. The Author prefers to soak the wood in acidulated water (1 of sulphuric acid to 5 of water), and then to heat slightly without exposing the wood to the direct flame. Dry rot is more difficult to combat. It is not essentially a vegetable production, nor is it contagious. Where iron is in

contact with the wood, impregnation with sulphate of copper is more injurious than useful, as in the presence of iron it is transformed into salts of iron. Instead of bolts of iron, bolts of acacia wood, as in use in the navy, are recommended. Several pieces of wood united under the surface of the earth are certain to become rotten. A triangular prism of concrete is recommended instead of traverses. One of the faces of the prism (of size proportional to the resistance) is to be perpendicular to the resultant of the tensions of the wire, and this is to be aided by a block surrounding the lowest portion of the pole.

P. H.

On the Application of Mechanical Means to the Sinking of Pits and Driving of Tunnels in Rock. By A. PERNOLET.

(Bulletin de la Société de l'Industrie Minérale, iv., 1874, pp. 595–709.)

This Paper is a continuation of one commenced by M. Pernolet in 1872. Since that time, the use of mechanical appliances for these purposes has considerably extended; various improvements have been made and several new varieties of apparatus introduced.

The subject is treated at great length under four principal headings, the first portion of the Paper being devoted to the consideration of the means employed for the production and distribution of compressed air. The actual amount of work which can be obtained from these machines may be judged by the fact that the force stored up in the compressed-air reservoirs by a Sommeiller compressor is only equivalent to from 35 to 40 per cent. of the steam power employed, and that the useful effect produced by the borers themselves amounts to only 20 to 25 per cent. of the steam power expended.

A considerable number of the most generally employed compressors are described at length, a comparison being instituted between machines into which only the air to be compressed is admitted and those into which a jet of water is at the same time introduced. The relative cost of compressing air by the various machines is also carefully considered, the results at Ronchamp during a period of six months showing that an outlay of from 0·015 to 0·02 franc is required for the production of 1 cubic mètre of air compressed to four atmospheres. Each of the machines described has its advantages and its disadvantages. To facilitate the choice of the most convenient form of apparatus for any particular case, a table is given showing the size, price, and other details of twelve varieties of compressors.

The second portion of the memoir is devoted to perforators, percussion apparatus, bits, and various accessories, a series of tables being given showing dimensions, weight, power, and consumption of compressed air by the three newest perforators, namely, those of MM. Ferroux, Burleigh, and M'Kean. For

very hard rocks the latter is especially recommended, whilst, for simplicity of mechanism, the perforator of MM. Dubois and François is to be preferred. Neither of the machines is, however, applicable to all purposes, and the choice of a perforator must be, to a great extent, governed by the description of rock likely to be met with. The bits vary in form according to the hardness of the rocks to be traversed, the Z form being used in soft rocks, and for harder rocks a bit with the cutting edges forming a right angle. The perforators are mounted, to the number of from six to ten, upon a carriage, the form most recommended being that of Marihaye.

The third portion of the memoir describes exhaustively the organisation necessary for carrying on work with mechanical perforators, and various details of matters connected with the practical carrying on of mechanical boring are discussed.

The fourth and last portion of the Paper consists of a comparison between the results obtained by hand boring and those realised by mechanical means, the data necessary for the comparison being taken from works carried on at the following localities: Mont Cenis, Vieille Montagne, Saarbrück, St. Leonard, Marihaye, Ronchamp, Anzin, and St. Gothard.

In conclusion, the Author remarks that the form of the gallery is more regular when mechanical borers are employed; that the daily progress, varying according to the number of perforators and the hardness of the rock, is from three to twelve times greater than with manual labour. More men are required when working by machinery as compared with hand labour, but considerably less skill. The economy obtained by the use of mechanical perforators ranges between exceedingly wide limits, varying from 7*s.* 1*d.* to 74*s.* 4*d.* for each yard driven, or from 7¾*d.* to 18*s.* 9*d.* per cubic yard of ground excavated. Mechanical borers are strongly recommended for large undertakings, whilst, for smaller work, extending over a considerable time, the advantages over manual labour appear, if they exist at all, to be reduced to a minimum.

The Paper is accompanied by a number of elaborate tables relating to the cost and efficiency of the various kinds of apparatus, and by eight large plates showing details of the machinery described.

A. G. P.

On Rock Drills. By Dr. Hartig.

(Civilingenieur xxi., part 2, cols. 149–158.)

The important improvements made in rock drills within the last five years consist chiefly, in a large reduction of movable parts. Whilst, for instance, in Sommeiller's percussion drill (1857) a complete rotary engine is employed to work the slide valve, in Darlington's drill (1873) a slide valve is entirely omitted, and the distribution of air is effected by the piston itself.

The development of rock drills tends to greater simplicity of construction, as may be seen by the table on the next page.

Year of First Application.	Name of Inventor.	Reversal of Stroke.	Twist of the Drill.	Advance of Engine.
1857	Sommeiller . . .	D valve worked by rotary engine .	Gearing worked by the same rotary engine.	Tappet, clutch gear, screw with part of a nut worked by the same rotary engine.
1863	Sachs	D valve worked by piston-rod and angle lever.	Ratchet worked by the same lever	Pair of screws, ratchet, and angle lever.
1868	Dubois and François	D valve worked through air-pressure by two auxiliary pistons, conical valve, tappet on piston-rod and angle lever.	Two auxiliary pistons, moved through the variation of pressure in the air-channels, work a side lever and ratchet.	Hand-power.
1869	Burleigh . . .	D valve worked by a tappet on piston-rod and angle lever.	Pair of screws of large pitch, ratchet and break.	Pair of screws, ratchet, single lever and tappet, or by hand-power.
1869	Osterkamp . . .	Cylindrical valve worked by air-pressure.	Bevel wheels and ratchet worked by the valve.	Hand-power.
1872	McKean	Oscillating valve worked by tappet and two angle levers.	Screw of large pitch and part of a nut.	The axle of the valve moves a nut whose screw is fixed in the frame.
1873	Azolino dell Aqua .	Distributing cocks worked by piston-rod through tap and curved slit.	Tap on piston-rod and curved slit.	The same as for the twist.
1873	Ferroux	D valve worked by rotary engine .	The same rotary engine . . .	Pressure of air on separate piston.
1873	Ingersoll . . .	Valve moved by piston through tappet.	Nut in piston, screw of large pitch and ratchet.	Pair of screws and ratchet worked by tappets.
1873	Braydon, Davison and Warrington (Power jumper).	D valve moved by levers from the two pistons.	Pair of screws of large pitch and ratchet.	Hand-power.
1873	Darlington . . .	Without slide valve, the piston itself effects the distribution of air.	Pair of screws of large pitch and ratchet.	Hand-power.
1874	Warsop	Rotary valve worked through the piston by a pair of screws of large pitch.	Hand-power	Hand-power, or in vertical holes through its weight.

Though the literature on the subject provides information as regards the construction of rock drills, their mounting on frames, and the details of air-compressors, the account of the work they are able to do is still far from complete. It would be useful to obtain for all of them such particulars as are given of the rock drill of Dubois and François: diameter of cylinder, 2·75 inches; diameter of piston-rod, 1·97 inch; total weight, 484 lbs.; weight of striking parts, 61·6 lbs.; number of blows per minute, 250 to 300; depth of holes, 3·94 feet; advance per hour in grey granite, 6·56 feet. The advance per hour in the same rock was found to be for

	Feet.
Sommeiller's drill	4·638
McKean's "	6·888
Ferroux's "	7·157

Amongst rotary drills, those with diamonds have been most improved. The 'diamond drills' of Leschot, chiefly employed in America, consist of a hollow steel tube, in the ring-shaped base of which between twelve and eighteen diamonds are so fitted, that each of them grinds a separate circle and leaves a cylindrical core to enter the tube. The rotary motion is effected by a small oscillating steam-engine, and the advance by a pair of screws, by hydraulic pressure, or by the dead weight of the rods. A jet of water, guided to the drill by the hollow rods, washes up the stone dust.

The process of sinking a hole consists in alternately boring and, if necessary, securing the hole by cast-iron tubes. As the steel part of the drill wears out very quickly, the diamonds fall out frequently, which, however, can be easily perceived through the consequent vibrations in the rods. The loose diamonds are brought up, after cleansing the hole with water, by a wax crown fitted in a steel ring. Other interruptions, arising from breakage in the rods, are rare.

The ratio of cost and time between different methods of drilling is shown in the following table:—

Method of Drilling.	For Depths to					
	394 feet.		787 feet.		1,182 feet.	
	Time.	Cost.	Time.	Cost.	Time.	Cost.
Hand-power	15	4	7	14	..	..
Engine with stiff rods	7	4	6	5	3	3
Engine with cord	5	3	5	4	3	2
Diamond drill	2	2	2	2	1	1

A comparison between percussion drills and (rotary) diamond drills shows that the latter involve a greater expense of 1·75 per cent., but afford a saving in time of 30 per cent.

G. K.

Applications of Electricity to Mining Industry, Torpedoes, &c.

By MM. Champion, H. Pellet, and M. Grenier.

(Annales de Chimie et de Physique, May 1875, pp. 28–114.)

The Authors begin by reviewing the various forms of induction apparatus for obtaining electric sparks, and the magneto-electric apparatus, chiefly of continental manufacture, now in use. Among the batteries, which are next considered, preference is given to those of the Leclanché type, with the advice that much better effects are to be obtained in firing fuses by employing larger surfaces of zinc than is common in this description of battery. The Grenet and Prud'homme batteries are recommended.

Wire conductors, as generally employed, are of copper, covered or coated with gutta-percha, to a thickness varying with the use for which the conductor is intended. For naval or military applications the gutta-percha is covered with tape saturated in caoutchouc varnish (caoutchouc dissolved in benzine). But gutta-percha proves in many cases defective: it becomes brittle with great cold, and melts at 104° to 122° Fahr. The solar rays are sometimes sufficiently powerful to put these cables *hors d'état*. Caoutchouc has been substituted; but, under the action of intense cold, even vulcanised caoutchouc deteriorates. It has been shown by Payen that vulcanised caoutchouc absorbs water; but this property does not materially affect the insulation when the insulating coating is sufficiently thick. The insulation of a conductor, whether more or less complete, presents no inconvenience with platinum-wire fuses, but only with those of the Abel type, which necessitate the use of electricity of high tension.

The most important section of this Paper is that relating to fuses, which have been subject to critical examination in their several kinds and purposes. The composition of Ebner's fuse is stated to be: sulphide of antimony, 44 parts; chlorate of potash, 44; plombagine, 12. It is here remarked that fuses should have the same electrical sensitiveness and resistance when intended for use in simultaneous explosions; otherwise the electric current will be unequally distributed, leaving some fuses not exploded. The examination into the construction and composition of Abel's fuse is very minute. The Authors find that analysis proves the ordinary published formulæ for the composition to be inexact. The correction is given as: protosulphide of copper ($Cu^2 S$), 16 per cent.; protophosphide of copper ($Cu^2 Ph$), 28 per cent.; chlorate of potash, 56 per cent. The protophosphide of copper is unknown, but is considered to result from the preparation in the following manner:—To the commercial phosphide (containing 20 per cent. of phosphorus) neutral red phosphorus is added in excess, and intimately mixed. This mixture is thrown into a crucible, and heated at dull redness until the greater part of the excess of phosphorus has disappeared; and, should an excess still appear, the

mixture is heated to very dull redness in a stream of hydrogen. A grey powder is thus obtained, corresponding exactly to the formula $Cu^2 Ph$. The sulphide, phosphide, and chlorate are mixed in presence of alcohol. This powder is stated to possess all the properties of the Abel composition as lately introduced. The construction of the fuse is detailed, and, with induction- or spark-fuses, the difficulty is dwelt upon of so adjusting the wires in each fuse as to present always the same electrical sensitiveness.

The sensitiveness of a powder to electric action may be inversely as its sensitiveness to explosion by percussion. If equal parts of fulminate of mercury and protosulphide of copper are thoroughly mixed in presence of alcohol, a powder is obtained very sensitive to electric action; but the addition of the sulphide much diminishes the sensibility to explosion by percussion. A powder of the Ebner type is diminished in sensibility to explosion by percussion proportionally with the quantity of carbon. Given an explosive mixture free from conducting substances, the facility it offers to inflammation under the action of the electric current increases proportionally with the quantity of inert conducting substances (plombagine, carbon, &c.) it contains; but this is within the limit at which the conductivity becomes too high for inflammation of the mixture. With regard to explosion by percussion, the inert conducting substance reduces the sensibility, and plays the part of silica added to nitroglycerine. The sensibility of a fuse depending very largely upon the diameter of the conducting wires, and the distance across which the spark must pass to inflame the explosive mixture, the Authors investigated the conditions of maximum effect, and arrived at the following conclusions:—The conducting wires should not exceed 0·9 millimètre diameter, nor be less than 0·2 to 0·3 millimètre. Theoretically, the distance of separation in the fuse should be the least possible; but practically 0·1 millimètre gives the best results, as the powder will not penetrate between wires at a less distance. With regard to the best mixture, the Authors find that, where high sensitiveness is required, Abel's composition is to be preferred; but, as it changes under test currents, it is not so well suited to military and naval purposes as Ebner's composition. A fuse should possess stability, when in the condition of powder between the separated wires, even in the presence of shocks and the prolonged vibration due to transport; and it should resist decomposition by the current from the testing battery. It is for the latter reason that the Authors give the preference to the Ebner composition where test-currents are necessary, but prefer the Abel fuse where extreme sensitiveness is required. The great difference in the resistances of chemical fuses is considered to be detrimental to their use in simultaneous firing, and it is said that there is no practical utility in rendering the resistance more constant by the use of a definite streak of plombagine, as in the Beardslee fuse, since in this case the resistance is adjusted independently of the explosive substance, and is no criterion of explosive sensibility. Fuses prepared by this method

may have the same resistance, but possess very different degrees of sensibility to inflammation. The fuse generally employed in France is the platinum-wire fuse, in which a platinum wire of $\frac{1}{18}$ millimètre diameter and 8 millimètres in length is heated or fused by the electric current, and inflames the explosive material. The regulation diameter is productive of the best results: if larger, the wire is difficult to heat; if smaller, its resistance necessitates the reduction of the distance between the conducting wires; and in this case the too near approach of the solder by which the platinum wire is secured to the conducting wire, and which absorbs a certain portion of the heat produced, impedes the incandescence of the wire. Collodion has been tried to protect the solder from the action of the sulphur of the composition, but it diminishes the sensibility of the fuse.

The remainder of the Paper is taken up with the reduction of Ohm's law to the determination of the number of elements necessary for firing a given number of fuses through a given conducting wire, and to the mounting of the various fuses, as they may be intended to inflame one or the other explosive.

P. H.

On the Carriage of Heavy Materials over High and Steep Watersheds. By JOSEPH SCHMIDTHAMMER.

(Oest. Zeitschrift für Berg und Hüttenwesen, May 10, 17 & 24, 1875, 6 pp.)

The Author deals with the principal combinations possible in the construction of railway inclined planes with rope traction for the conveyance of minerals, and the conditions under which the work developed by the descending load can be utilised in raising the return load. The conditions investigated embrace the use both of ropes winding upon drums and endless ropes moving continuously. By placing a motor at the summit of the line, and combining the head pulleys of the opposite inclines by appropriate conical gearing, the Author considers that the use of motive power will only be necessary to overcome the resistance of the load at starting, and that the excess of power on the descending load on either line may be made to act in pulling up the load upon the opposite rope. The Author considers that the best line is that with three rails and crossing places, as being nearly equal in carrying power to a double line, though much cheaper on account of the lesser width of the road bed, a point of considerable importance in mountain lines. From the results of several examples he shows that the use of an endless rope is not attended with any mechanical advantage over ropes winding on drums when the inclines do not exceed 1 in 7 and 1 in 9; but that on the steeper gradients of 1 in 4 and 1 in 5, the resistance at starting is about 30 per cent. less with a continuous than with an alter-

nating system of traction. The power available by the combination of two inclines, recommended by the Author, is estimated at about one-half of that required to lift the ascending load.

H. B.

On the Winding Engines at the Adalbert Shaft at Pribram, in Bohemia. By JOHANN NORÁK.

(Oest. Zeitschrift für Berg und Hüttenwesen, March 1, 8, 15, and 22, 1875, 8 pp.)

The work for which these engines have been designed is the drawing of a load of 112,000 tons per annum from a depth of 3,673 feet (nearly 200 feet more than the height of Snowdon), in sixteen working hours per diem. As the dimensions and arrangements of the shaft do not permit of the use of double-decked cages, the largest load that can be drawn at one time is 1 ton, so that the cage has to make one hundred and twelve thousand trips annually, which, for three hundred and fifty working days, gives twenty trips per hour, corresponding to a mean velocity, including stoppages, of 20 feet per second. The maximum velocity required to attain this result is 31 feet per second. With these data the Author proceeds to calculate, in detail, the form and dimensions of the winding gear according to different systems of construction. He finds that conical drums, with a spiral bed for the round drawing ropes to coil on, would have required to be of such large dimensions as to be unmanageable, the result of the calculation giving a maximum diameter of 43 feet, a minimum diameter of 31 feet, and a breadth of 20·6 feet.

The use of flat ropes coiling upon a bobbin increasing continuously in diameter by the overlap of the ropes, was also found to be disadvantageous; for although the calculation showed a slight gain mechanically, this was more than counterbalanced by the increased cost of the rope. This condition, also, was only true for the greatest depth; and as the mine is worked at several different levels, calculations were made for depths of 3,280 feet, 2,625 feet, 1,969 feet, 1,313 feet, which gave as a result that at 2,625 feet practically the maximum power of the engines would have been required to start the load.

The Author considers that the supposed greater durability of flat as compared with round ropes is to be attributed to the fact that the former are usually of a proportionately heavier section than the latter, and that too small a diameter of drum is often adopted for round ropes. When flat and round ropes are made so as to be strained equally, and the proper diameter of drum is chosen, the latter will certainly wear as long as the former. The experience already derived from the use of round steel wire ropes at Pribram bears out this conclusion, where they are found to stand two years' continuous wear, or more even in one instance. The final selection, therefore, was a tapered steel wire rope, of

circular section, with a breaking strain of 72·1 tons per square inch, assuming sixfold safety strength in the working strain.

The taper of the rope is arranged in the following manner; the number of wires is thirty-six throughout:—In the lowest length of 328 feet, they are of No. 11 Styrian gauge (0·075 inch diameter); in the second length of 590 feet, of 0·079 inch; in the third of 918 feet, of 0·088 inch; in the fourth of 918 feet, of 0·098 inch; and the remaining 918 feet, of 0·103 inch. The total weight is—

	Feet.	Cwts.	lbs.
Section 1	328	2	5
„ 2	590	4	19
„ 3	918	8	16
„ 4	918	10	0
„ 5	918	11	2
	3,672	35	42

Or only about half the weight of a flat rope of equal strength. The diameter of the drums was determined so as to take the whole of the rope in two thicknesses, as experience showed that the tapered end, when lapped a third time, is liable to become wedged in the hollows between the thicker portions below, which causes the wires to bend and be torn. Of course the great length precluded the possibility of coiling the rope in a single layer. The final dimensions chosen were 19·7 feet diameter, and 2·75 feet breadth of face, which, at seventy-two coils in a double layer, gives a capacity 4,451 feet, or about 790 feet more than the present requirements.

It might be supposed, from the absence of any means of balancing the weight of the rope, that the difference between the power required to move the load at the beginning and ending of the journey would be greater than with flat ropes. That this is not the case, however, will be seen from the following table, which supposes a mean speed of 20·4 feet, corresponding to twenty revolutions per minute, and 54 HP. for engine resistance, &c.:—

Depth in Mètres.	Radius of Drums in Mètres.	Load at Starting, in Kilogrammes.		Load at End, in Kilogrammes.		Horse-Power of Engine.		
		+	−	+	−	Starting.	End.	Difference.
1,120	3	3,590	790	1,790	2,590	+ 286	− 12	298
1,000	3	3,350	790	1,790	2,350	+ 266	+ 8	258
800	3	2,958	790	1,790	1,958	+ 234	+ 41	193
600	3	2,598	790	1,790	1,598	+ 204	+ 69	135
400	3	2,289	790	1,790	1,289	+ 178	+ 95	83

The difference between the power required at the beginning and ending of the journey never reaches 300 HP., whereas it was slightly exceeded with the flat rope at 2,625 feet. The break was only necessary when drawing from the greatest depth, whereas with the flat rope it was required at 2,625 feet and 3,280 feet.

From the considerations given above, the following conclusions are drawn:—

1. That it is not desirable, in winding from depths exceeding 2,300 feet, when only a light load is drawn, to use flat ropes, as any slight equalisation of balance obtainable is not in proportion to the extra cost.

2. Spiral rope drums cannot be used for great depths, as they must be so large and heavy that the power saved by the counterbalancing of the ropes is lost by the increased friction on the bearings.

3. For shafts of 1,300 feet and less, flat ropes are not to be recommended, as with a tapered round steel rope at such depths no counterbalancing of the ropes is necessary.

4. For shafts between 1,300 feet and 2,300 feet deep, where a heavy load has to be drawn, flat ropes may be advantageously used, especially if the principal workings are at the lowest point in the shaft. For these dimensions, however, spiral drums are expressly suited, as they may be made of reasonable size, allow for a perfect counterpoise of the ropes, and are also better protected against wear than plain drums.

The construction adopted for the engines was horizontal and direct-acting. The cylinders are 20·8 inches diameter, with a length of stroke of 6·6 feet. The steam pressure on the boiler was $7\frac{1}{2}$ atmospheres, and the initial pressure on the piston $6\frac{1}{2}$ atmospheres, the maximum duty of 300 net HP. being attained with the cylinders $\frac{7}{8}$ full, and twenty revolutions per minute. The mean duty of about 130 HP. is attained with a steam admission of $\frac{1}{8}$ of the stroke.

In order to obtain the utmost variation in the degree of expansion, a modification of Meyer's expansion gear is adopted, in which the face of the expansion slide is cylindrical, and moves on a surface of corresponding curvature at the back of the steam slide. The steam ports and the passages in the slide are skew to the axes of the cylinders; and as the expansion slide can be rotated on its bed by turning about its centre, the cut-off may be varied within the widest possible limits. Owing to the peculiar form of the slides, which have spiral ends, each end of the cylinder has its own admission, exhaust ports, and slide valves, as in the older forms of long-stroke vertical engines. The variation in the steam admission is between 0 and $\frac{13}{16}$ of the length of stroke, which extremes are obtained by turning the expansion slide through an angle of 94°. The reversing of the engines is effected by Gooch's link motions, and the movement of the expansion slides by special eccentrics. These eccentrics are driven by an independent shaft connected with the drum axle by spur gearing, an arrangement

which allows the eccentrics to be made of smaller dimensions than is the case when they are fixed on the main shaft.

With the exception of the pistons, which are of wrought iron, all the moving parts of the engines are of Bessemer steel. The main shaft is about 15 inches in diameter, and 15 feet long. The drums are made with twelve radial wrought-iron arms of a ⊔ section, and cast-iron seatings. The rims are of wrought iron, with a wooden bed for the rope, the sides being braced together by diagonal intersecting ties. The reversal of the movement is effected by a water-pressure engine acting directly on the link motions, about $\frac{3}{4}$ HP. being sufficient to pull over the links when making twenty revolutions per minute. For ordinary working a steam break is provided, which can also be operated by hand, if necessary. The engines, which were constructed by the Prague Engine Building Company, work more economically than similar engines already in use at Pribram, in which the expansion is effected by slides and link motion alone, the relative consumption of fuel being in the proportion of 7 to 10. The Author, however, proposes to make further detailed communications upon the subject.

H. B.

The Winkeln-Appenzell Railway.

(Die Eisenbahn, June 4 and 11, 1875.)

The construction of a line from Winkeln or Gossau, on the United Swiss railway to Herisau, and eventually to Urnäsch and Appenzell, although very desirable, was long delayed in consequence of the alpine character of the country, and the consequent great cost. The mètre gauge being decided upon as most suitable for the small curves and close adherence to the conformation of the ground, the first portion was at last begun, and on the 12th of April the short line from Winkeln to Herisau, a distance of 2·5 miles, was opened for traffic. On the entire line, the length of which is 15·5 miles, the sharpest curves have a radius of 295 feet, and the greatest incline is 1 in 28·5; the height of the rails is 3·94 inches, the width of the foot is 3·54 inches, the thickness of the web is 0·47 inch, the weight 57 lbs. to the yard, and, with 3 feet between the centre of the sleepers, they are calculated to support a maximum weight of 3·5 tons. The completed portion is the most unfavourable as regards the configuration of the ground and its geological character. The rise from Winkeln to Appenzell is 354 feet, which has to be surmounted in 2·48 miles, the first 298 feet of which are within 1·86 mile. In consequence of the ravines and broken nature of the ground, it was impossible to adopt larger curves; indeed, it was found necessary to lay one of 275-feet radius; but the speed has been fixed by the concession at a comparatively low rate, there being fourteen trains each way per day, which complete the journey in fifteen minutes, or at the rate of 10 to 12·5 miles per hour.

The locomotives, built at the Swiss Locomotive Factory at Winterthur, have answered every expectation; and, though accurate data as to the consumption of coal are yet wanting, 17·6 cwt. may be adopted as the quantity for the fourteen double journeys per day, the fuel for the downward portion being of course but slight. The principal dimensions of the locomotives are as follows:—Wheels: diameter, 2·95 feet; distance between leading and centre axle, 3·6 feet; total wheel-base, 7·05 feet. Cylinder: diameter, 12·2 inches; stroke of piston, 17·7 inches; distance between centres, 6·06 feet. Frame: overhang in front, 5·4 feet; in the rear, 7·5 feet; length, without buffers, 20 feet; with buffers, 23 feet. The distance between the centre of the boiler and the top of the rails is 4·9 feet; the internal length of the fire-box is 3·55 feet, the internal breadth 2·36 feet, and the height 3·76 feet. There are one hundred and twenty-four tubes, each with an internal diameter of 1·77 inch, and a total heating surface of 593·52 square feet; the weight, when empty, is 15·9 tons, and when in use, 19·5 tons; the proof pressure is 10 atmospheres, and the HP. 120. A velocity of 10 miles an hour, or 14·6 feet per second, requires 3·1 piston strokes per second, which has been found perfectly feasible, although it was feared that unendurable oscillation would be the consequence, and that the diameter of the driving wheel would have to be increased to 3·28 feet. These engines perform their work with regularity, and in ordinary weather easily take trains of 40 tons weight.

J. D. L.

Mountain Railways. By C. Maader.

(Zeitschrift des Oest. Ingenieur u. Architekten Vereins, No. 13, 1874, pp. 213–219.)

This article refers to railways generally, and to the models thereof at the Vienna exhibition in particular. Mountain railways, as here defined, are those lines which ascend very steep acclivities by means of exceptional gradients. They may be classed under two heads: 1st. Those lines worked with wire ropes and stationary engines; 2ndly. Those on which locomotives of peculiar construction are used. In the first class are four lines carrying goods and passengers. The Ofner railway, which was opened for traffic in 1869, has a horizontal length of 262 feet, and a vertical height of 164 feet, equal to a rise of 1 in 1·6. The engine at the foot of the incline has two cylinders, with a diameter of 15·7 inches each, and a stroke of 24·8 inches. The wire rope, which is composed of six strands of six wires each, is 0·98 inch in diameter, and coils round two cast-iron drums 9·8 feet in diameter, one of which winds as the other unwinds it. In addition to the rope break, a contrivance is provided for arresting the train if the rope should snap.

The rope railway at Leopoldsberg, near Vienna, which is 2,378 feet in length, rises with a mean gradient of 1 in 3 to a height of 1,125 feet, the road, with the exception of two reverse

curves of 6,560-feet radius, being straight. The high-pressure winding engines are placed at the head of the incline, with cylinders of 24·8 inches in diameter, and a stroke of 6·23 feet. A steam break controls the ropes, which are of cast steel 1·96 inch in diameter, composed of strands each 0·055 inch to 0·12 inch thick. At each end of the rope is a passenger car of two stories, capable of carrying one hundred persons. The break power consists of a second rope of the same strength, attached to the cars at each end, and winding round a horizontal drum 19·68 feet in diameter at the upper station, by which both cars can be kept in equilibrium should the drawing rope break. The passage occupies five minutes, being at the rate of 475 feet per minute. The line commenced working in 1873, and in one hundred working days carried three hundred thousand persons.

The Croix-rousse rope railway, near Lyons, has a horizontal length of 1,604 feet, and uniform rise of 1 in 6·25, equal to a total vertical height of 230 feet. In this case also the engine stands at the head of the incline; the drum has a diameter of 14·8 feet, and is provided with two powerful steam breaks; the winding rope, which is 2·36 inches in diameter, consists of seven smaller wires, each of which is composed of thirty-six strands 0·079 inch thick. A train of three cars, carrying a total of three hundred and twenty-four persons, is attached to each end of the rope; the transit, at the rate of 469 feet per minute, occupies three minutes; and a daily number of thirty thousand persons, and provisions for forty thousand, are constantly carried. Besides an apparatus for griping the head of the rail to prevent the sliding of the wheels, these latter are also held by powerful steel bands, which successfully act as breaks when occasion requires.

The rope railway at Pittsburg, in America, has a horizontal length of 630 feet, and a vertical height of 364 feet, equivalent to an average rise of 1 in 1·72. The engine-house at the top contains a high-pressure steam-engine with two cylinders, each 11·8 inches in diameter and with a stroke of 23·6 inches. Round the iron drums, of 8·8-feet diameter, are coiled ropes 1·3 inch each, composed of one hundred and fourteen strands. The break arrangement is similar to that of the Leopoldsberg railway. At each end of the rope is a car, with twenty-five seats, travelling at a velocity of 797 feet per minute. Throughout its whole length this line consists of an iron superstructure resting on iron piers.

In the railways described above the weight to be moved exerts a direct pull on the rope, requiring a maximum strength in all the moving parts of the machinery; in the method employed by Riggenbach and Zschokke, a drum, furnished with a toothed wheel working into a rack laid between the rails, is attached to each carriage, and round it works the traction rope. This rope is carried round pulleys with a diameter sufficiently large to obviate damage, drums being dispensed with. The rack movement enables the train to be brought up at almost any point; and through the

absorption by the rack of a great portion of the dead weight of the train, the driving rope can be slighter and more pliable. The difference between this and the Rigi system lies in the rack, which in the former case is laid on the ground, whilst in the latter it is carried by two bearers, each 7 inches thick. In the middle of the track, at about 29·5 feet apart, are two rollers to guide the rope; while at each end of the line are drums 9·8 feet in diameter, the upper one moved by water or steam. The rotation of the drums at the head of the incline imparts motion to the endless rope which moves the two driving discs of the driving cars, one of which is attached to each ascending and descending train. The driving car consists of a frame resting upon two axles, carrying a toothed wheel connected with the driving discs, and griping in the rack. The breaks are effectively worked from the platform of the car.

Of true mountain railways worked by locomotives there are two systems, the one employed by Mr. Fell, and the other by Messrs. Riggenbach and Zschokke. On Fell's line over the Mont Cenis the gradients are 1 in 12, with curves of 131·2-feet radius; but the principle on which this railway is constructed is too well known to need explanation.

The Rigi railway when first opened required but three locomotives; it now employs thirteen, and it is expected that this number will be soon increased to thirty. In Switzerland eight lines provided with the central rack have been either constructed or are in various stages. The line from Heidelberg to the Königstuhl was freed from all imperial and municipal taxation for twenty-five years.

The concession for the railway to the Schwabenberg at Ofen was for forty years, all land being granted free, and taxation remitted for fifteen years. It is connected with a tramway to the suspension bridge at Pesth, and has nearly continuous gradients of 1 in 10, its length being about 2 miles, and total rise 852·8 feet. The track itself is a single one, but land and works have been taken for a double line. It assimilates to the Rigi line, but the boilers are flat, and the engines drag three cars each. It was commenced in the summer of 1873, and opened for traffic in the following year. M. Cathray, a Swiss, was the engineer.

In May 1873 a line to the plateau of the Kahlenberg was begun, and opened in ten months. It received no advantages beyond the mere concession; and owing to the exorbitant demands of the landowners it proved a commercial failure, the payments to them amounting to £50,000 on a line of only 3·1 miles in length. Like the previous lines, it is constructed on the Rigi principle, except that the locomotive boilers are flat. The rail is also heavier, weighing 40 lbs. per yard, as against 33 lbs. per yard on the latter line, although four years of wear have failed to injure the Rigi rails. The centre rack between the rails is composed of two U-shaped pieces of rolled iron, into which the wrought-iron teeth forming the rack are placed when the former are hot, and

they are secured in position by the contraction of the metal. The rack is formed in lengths of 9·8 feet, and weighs 36·9 lbs. per lineal foot. The horizontal length of this line is 164,000 feet, with a total rise of 918·4 feet, the minimum gradient being 3 per cent., and the maximum 10 per cent. In laying the permanent way, oak sleepers, 2·46 feet apart, were screwed into longitudinal larch sleepers; while at every 328 feet are two stone blocks to prevent lateral movement. Each train consists of three wagons of fifty-four seats each; they travel at about 7 miles an hour. Every train is provided with tools, during its half-hour's run, in case of accident, though the Author is firmly convinced of the complete safety of the central rack system. The rolling stock consists of six locomotives, eighteen passenger carriages, and four goods wagons; twelve thousand to fifteen thousand persons per day can be conveyed. The telegraph is employed in signalling and working the line.

The Ostermundingen railway was constructed three and a half years ago, by Messrs. Riggenbach and Zschokke, to open up certain quarries, as well as for passenger traffic. After a level run of 4,920 feet, it rises, with a gradient of 1 in 10, for a distance of 1,640 feet, where it again takes a level run into the quarries. The central rack rail is only laid on the rising portion of the line, the locomotive being constructed so as to work like an ordinary engine until it reaches the ascent, when the machinery is put in gear with the rack. This railway connects with one of the main lines of the country, the goods wagons used on both lines being the same; and the Author considers that the construction of this line solves the problem of combination between the mountain and main-line systems.

H. T. M.

Rapid Transit and Terminal Freight Facilities.

Report of a Committee of the American Society of Civil Engineers.

(Transactions of the American Society of Civil Engineers, April 1875, pp. 1–80.)

A committee was appointed, in September 1874, to investigate and report upon, 1st, The best means of rapid transit for passengers; 2ndly, The best and cheapest methods of delivering, storing, and distributing goods and freight, in and about the city of New York. This notice is confined to the first of these questions.

It is admitted that an enormous traffic may be secured, but that to carry out successfully a sufficient scheme of rapid transit the fares should be as low, or nearly as low, as upon the street railroads that now run through the city; and the committee considers "that such roads can be made to pay upon a volume of traffic not much, if any, greater than that now carried upon existing street car lines; that the business is likely to grow very fast; and that, so soon as the population has adjusted itself to the new facilities furnished, the

volume of traffic which may legitimately be expected will pay large returns upon the investment required, if the roads are judiciously built." But there follows a warning that "rapid transit in New York is so nicely balanced between financial success and failure, that it cannot afford to pay for mistakes, either in principle, policy, or material detail."

The magnitude and distribution of the existing traffic of New York by tramways and omnibuses is exhibited in the following abstract:—

NUMBER of PASSENGERS CARRIED by HORSE RAILROAD and OMNIBUSES, during the YEAR ending SEPTEMBER 30, 1873.

	Passengers.
Third Avenue (8 miles of road, or 18 miles of track)	26,950,000
Eighth Avenue (10 miles of road)	15,143,048
Broadway and Seventh Avenue	17,883,776
Sixth Avenue	14,747,141
Dry Dock and East Broadway	15,536,160
Central Park, North and East River	11,389,957
Second Avenue	13,570,955
Forty-second Street and Grand Street Ferry	6,812,759
Bleecker Street and Fulton Ferry	5,057,191
Avenue C	3,538,710
Ninth Avenue	1,784,346
Fourth Avenue	8,730,888
Omnibuses	7,000,000
Total passengers	148,144,931

Showing a total of nearly one hundred and fifty million passengers in the year. Now, at a rate of fare not materially greater than that charged on the horse railroads (or tramways), say 6 or 7 cents (3*d.* or $3\frac{1}{2}$*d.*) for a distance of about 5 miles, or $1\frac{1}{4}$ cent ($\frac{5}{8}$*d.*) per passenger per mile, it is maintained, in general terms, that a volume of traffic equal to that passing over the Third Avenue railroad, say twenty-seven million passengers per year, would warrant an expenditure for the construction and equipment of a rapid-transit road of about $935,000 (£194,800) per mile of double track; and that fifteen million passengers per year, equal to that of the Eighth Avenue line, would pay on an expenditure of about $650,000 (£135,400) per mile. Rapid-transit lines, in the vicinity of these routes, ought to do even more business in developing traffic by settling the upper part of the island, which would in a few years, it is estimated, be equal to thirty-five million passengers per year on each side of the island, and would warrant an expenditure of about $935,000 (£194,800) per mile of road.[1]

In carrying thirty-five million passengers per year, or say one hundred thousand per day, it is probable that half this number would be moved one way during three hours in the morning, and

[1] Reference is made to the Metropolitan railway, London, which carried 44,118,225 passengers in 1874.

back in the same time in the afternoon—say fifty thousand in six hours, or about eight thousand four hundred passengers per hour in one direction. This would require two hundred and ten cars per hour, with forty-six seats, holding an average of forty passengers each; say seventy trains of three cars each, or forty-two trains of five cars each. At the speed of horse-cars, this may be done on a double line of way; but, to work the traffic at a higher speed, it is considered that the rapid-transit roads should not only be double-tracked over the whole of the route, but quadrupled below the point where business is most concentrated; also that, though express and mail business may be done, it is not practicable to run freight trains on such lines.

The prevailing gauge of the New York lines, 4 feet 8½ inches, would be adopted. The New York Elevated Railroad has a gauge of 4 feet 10 inches, which is likely to be altered to the standard gauge.

The topography of the island indicates that there should be two rapid-transit roads, one on the east side and another on the west side of the Central Park, the whole being worked together as a belt or circuit. In preference to the 'underground' and the 'depressed' systems, the 'elevated' system of railway is recommended, as the most convenient and the cheapest. The leading elements of the cost of an elevated road are, first, the rolling weights to be carried; and, second, the position to be occupied in the street. With respect to the rolling weights, the following table shows the load imposed by trains on different spans of bridgework, including that of the trains proposed by the committee;—

Load imposed by Trains on different Spans.

Trains.	Span, 30 feet.		Span, 40 feet.		Span, 50 feet.		Span, 60 feet.	
	Total Weight.	Per Foot of Span.	Total Weight.	Per Foot of Span.	Total Weight.	Per Foot of Span.	Total Weight.	Per Foot of Span.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Ordinary .	80,000	2,666	91,350	2,284	102,700	2,054	122,700	2,045
Cars alone .	45,400	1,513	45,400	1,135	45,400	908	56,750	946
N.York Elevd.	19,800	660	23,000	575	32,200	644	38,200	637
Proposed .	18,000	600	22,500	562	27,000	540	36,000	600

The proposed train-weight on a 30-feet span does not exceed 600 lbs. per lineal foot; but the committee recommend that provision should be made for a rolling load of 1,200 lbs. per lineal foot of each track, to cover contingencies, and that the factor of safety should be from 5 to 6.

With respect to position in the street, there is an advantage for cheapness of construction in narrow streets, about, say, 20 feet

wide, where the supporting iron columns can be placed just inside the kerb-line, and surmounted by lattice girders. On this system the work has been estimated by Messrs. Buel, for an assumed rolling load of 1,500 lbs. per lineal foot, to cost $450,000 (£93,750) per mile of double track. In the avenues, which are 60 feet wide between the kerbs, the tracks may be constructed close together over the middle of the road, supported on columns, which would cost $300,000 (£62,500) per mile; or separately, one track over each side of the street, which would cost from $300,000 to $350,000 (£62,500 to £72,920) per mile of double track, exclusive of stations and rolling stock.

Rolling Stock.—The following comparative weights of the trains on ordinary railroads, and on the New York Elevated Railroad, show the great difference in favour of the latter, which is worked by four-wheeled locomotives weighing 10,600 lbs.:—

	Ordinary Train.	New York Elevated Train.
Total length of wheel-base	372 feet 2 ins.	125 feet 9 ins.
Total weight of train, with cars filled with passengers	372,400 lbs.	65,800 lbs.
Weight of cars and locomotive, per passenger	1,034 ,,	457 ,,
Maximum weight per wheel	10,000 ,,	2,650 ,,

It is recommended that the cars be made similar to those in use on the Elevated Railroad. The weight of such cars, to seat forty-eight passengers, would be only 10,800 lbs., or 225 lbs. per passenger. The capacity of the cars could be increased by providing seats on the roof. The locomotives employed on the Elevated Railroad are small four-wheeled ones, weighing 10,600 lbs., and it is believed that similar ones, but about 1,600 lbs. lighter, will answer all the requirements. Assuming that the steepest gradient will be 80 feet per mile, it is estimated that the total resistance of the proposed train of three cars and the locomotive would be 1,260 lbs.; whilst the weight of the proposed locomotive, 9,000 lbs., would be seven times as much. Should heavier and more powerful engines be required, it is proposed to use a bogie-engine, and to apply a pair of steam-cylinders to the wheels of the bogie, to utilise the weight on the bogie for adhesion.

After a consideration of the 'Location of Routes,' and the means of finding the capital, the committee arrives at the following conculsions:—1st. That double-track rapid-transit roads should be designed so as to cost, fully equipped, not much, if any, more than from $700,000 to $1,125,000 (£145,800 to £234,400) per mile, and this points to some form of elevated railroad as the leading feature of the design. 2ndly. That the right of way must be given for the roads, and they should be worked by means of locomotives and cars much lighter than ordinary stock. 3rdly. That the character of the structure carrying the roads should vary with the location, according to circumstances. 4thly. That two roads should be constructed at once, one on the east and the other on the

west side of the Central Park, to be supplemented by others. 5thly. That an effort should be made to induce private capital to take up the system; and that, if it fails, the lines should be assumed by the city and built as municipal works.

In a note the following table is given, abstracted from the larger tables which accompany the Paper, showing the average train-mileage, with the cost, earnings, and profit of running trains on the proposed rapid-transit roads of 5 miles in length, in order to carry from five million to thirty million of passengers per year. It is assumed that only 45 per cent. of the seats are occupied, in trains consisting of three cars, with forty-eight seats in each, and that the fares are charged at the rate of $1\frac{1}{4}$ cent ($\frac{5}{8}d.$) per mile:—

ESTIMATED COST, EARNINGS, and PROFIT of PASSENGER TRAFFIC on the RAPID-TRANSIT RAILROAD.

Number of Passengers conveyed per Year.	Number of Train-miles.	Total Cost of running Trains.	Cost per Train-mile.	Earnings per Train-mile.	Profit per Train-mile.
	Miles.	£.	d.	d.	d.
5,000,000	354,410	38,315	25·94	38·88	12·94
10,000,000	708,820	62,987	21·33	38·88	17·55
15,000,000	1,063,230	90,646	20·46	38·88	18·42
20,000,000	1,417,640	115,411	19·44	38·88	19·44
25,000,000	1,772,050	147,222	19·93	38·88	18·95
30,000,000	2,126,460	173,966	19·61	38·88	19·27

D. K. C.

On the Use of Steel in the Construction of Permanent Way.

By A. HUBERTI.

(Revue Universelle des Mines, Jan. and Feb. 1875, pp. 187–200.)

This Paper deals with a series of reports sent in by the officials of the principal German railway companies to the "Verein" of German railways, on the occasion of its sixth meeting, at Dusseldorf, in September 1874, in answer to the following questions:—

What are the results of recent experience in the use of Bessemer steel rails, more especially as to notching the flange, or the arrangements proposed to take the place of notching?

Have any recent trials been made of rails with heads of Bessemer steel and flanges of fibrous iron?

To what causes are the breakages of steel rails to be attributed?

The majority of the companies, in reply to the first question, pronounced strongly against notching steel rails and reported, that the most frequent, and in some cases the only, breakages on their lines had occurred at the notches. Others, however, notably

the Theiss, Prince Rudolph, and Baden State railways, stated that on their lines no rails had been found so to break.. In no case are any particulars given of the form and size of the notches, or whether they had been made by filing or by cutting. On the Upper Silesian railway, out of fifty-two thousand six hundred and twenty rails put down since 1872, only sixty-nine had broken, of which twenty-eight broke through the bolt-holes, four through the notches, and thirty-seven in the full section. On the Rhenish railway, notches in steel rails, less deep than those generally used in iron rails, were insufficient to prevent longitudinal displacement; but even in using these, the breakages were 10 per cent. through the bolt-holes, 20 per cent. through the notches, and 70 per cent. in the full section. This company has now given up notching steel rails.

Half-circular notches, filed out, had been tried on the Berlin-Anhalt railway, the result being that breakages of the rails seldom occurred at the notches, but, as on the Rhenish railway, these had not been sufficient to prevent displacement.

The substitutes for notches adopted by different administrations to prevent longitudinal displacement of the rails are stop-plates (Vorstossplatten), stop-angles (Stosswinkel), and angle fish-plates (Winkellaschen). The stop-plates and stop-angles are small plates, more or less curved, firmly spiked through the chair-plates (where these are used) to the sleepers at the sides of a suspended joint, and butting against the ends of the fish-plates. The angle fish-plates are rolled with a projecting flange at the base, which is either notched to receive the spikes or simply butts at its ends against their heads, or directly against the sides of the sleepers. All these methods are reported to be equally effective. Stop-plates are used on the Brunswick, Breslau-Schweidnitz-Freiburg, Leipzig-Dresden, Magdeburg-Leipzig, Main-Weser, East Prussian, and other lines; and angle fish-plates on the Bergisch-Märkisch, Hanoverian State, Rhenish, Emperor, Ferdinand, North railways, &c.

On the Brunswick railway, with inclines of 1 in 80 to 1 in 140, each sleeper that takes the longitudinal thrust of the rails is kept in place by struts laid in between it and the next sleeper. On the Cologne-Minden railway the rails of single lines are not notched at all, and show no tendency to shift longitudinally. On the double lines of this railway the fish-plates project downwards below the flanges of the rails, and take a direct bearing at their ends against the sides of the sleepers, into which they penetrate 1·2 inch, and the sleepers themselves shift under the pressure as much as 5·5 inches. On the Main-Weser and East Prussian lines corner notches are used in the case of rails laid with supported joints, and in suspended joints stop-plates are fixed on the outer side of the rail. On the Westphalia railway the angle fish-plates are not arranged, as elsewhere, to act at the same time as ordinary fish-plates, but are bolted on outside of and in addition to these, their sole office being to prevent longitudinal movement.

An alternative plan to those above described is proposed by the

Breslau-Schweidnitz-Freiburg railway company—this is to interpose a notched iron rail after every three or five steel rails, to take up the longitudinal thrust.

In answer to the second question, as to the result of recent trials of rails rolled with heads of Bessemer steel and flanges of fibrous iron, the Kiel-Altona, East Bavarian, Bavarian State, Brunswick, and Saxon State railways reported in favour of such rails, and considered that it was perfectly possible to obtain a good weld between the iron and the steel, particularly if the weld was arranged to come midway up the web. Two companies only, the Bergisch-Märkisch and the South Austrian, considered that a sound weld was impossible.

The third question, to what causes the breakage of steel rails should be attributed, was replied to by twenty-four administrations. Among the causes suggested were :—1. The use of steel too hard or too brittle. 2. Manufacture at too high a heat. 3. Rolling at too low a heat. 4. Irregular or too rapid cooling of the finished rails. 5. Injury done to the rails in cold-straightening, which causes minute cracks, and ultimately leads to breakage. 6. Similar injury by careless handling of the rails, such as throwing them roughly out of trucks on to the ground, or by curving them in laying them down in curves. 7. Notching in the flange. 8. Punching the bolt-holes instead of drilling them; and 9. The reduction of the section of the rails at the bolt-holes.

On the use of steel points and crossings much difference of opinion was expressed; some of the railway administrations condemning them altogether as unsafe, while others, that of the Empress Elizabeth railway, for instance, recommended them strongly. The conclusion of the commission was that rails of Bessemer steel showed much greater durability and more regular wear than those of iron or puddled steel, and that, though a certain number of breakages had taken place, their more general use could not but be recommended.

W. H.

On the Manufacture of Steel-headed Rails at Zwickau, in Saxony.

By A. Petzhold and Heusinger von Waldegg.

(Organ für die Fortschritte des Eisenbahnwesens, vol. xi., parts 5 and 6, pp. 224–234.)

The Königin Marien Hütte iron works near Zwickau, in Saxony, have obtained a high reputation for a class of steel-headed rails differing in many particulars from those made at other works on the Continent, but more especially in the welding of the two metals. The steel for the head is mild Bessemer metal, made from pig iron, containing a considerable percentage of manganese and without spiegeleisen. The ores are derived from eighty different mines belonging to the works, situate in various parts of Saxony,

Bavaria, and Thuringen. The average percentage of iron is as follows:—

Red hæmatites, from lodes in granite, in the Saxon Eizgeberge, containing manganese but free from phosphorus, up to 55 per cent. of iron. More silicious varieties from Bavaria, 45 per cent.

Magnetic ores. Saxon up to 60 per cent. Bavarian up to 40 per cent.; the latter are somewhat pyritic.

Brown iron ores and altered spathic ores, up to 35 per cent.

Liassic ore from Upper Franconia, somewhat sandy, up to 40 per cent.

Spathic ores from Thuringen and Reuss, up to 35 per cent.

Nodular clay iron ore from the coal measures of Zwickau, up to 40 per cent.

The brown ores and coal-measure carbonates are roasted in heaps; the other kinds are charged into the furnace without roasting. The charges for Bessemer iron consist of mixtures of red hæmatite and spathic ores, the other varieties being used in the furnaces producing foundry and forge pig iron. The average production of the Bessemer iron furnace is from 100 to 125 tons per week, from charges containing from 35 to 40 per cent. of iron. The average composition of the Bessemer pig is given by the following analysis:—

Carbon, combined	1·095	Manganese	3·450
„ graphitic	2·936	Phosphorus	0·070 to 0·120
Silicon	2·200	Sulphur	Trace.

The re-melting for the converter is effected in a cupola, limestone being added to produce a fusible slag. The charge consists of a mixture of the local metal with hæmatite pigs and other kinds from Osnabrück and Siegen, and a proportion of steel waste.

The Bessemer works contain two 5-ton converters, blowing from thirteen to fourteen charges in twenty-four hours. The duration of the blow is from fifteen to eighteen minutes, the end of the operation being determined by the disappearance of the sodium line in the spectrum. A curious group of bright lines, very commonly observed in the green and blue field of the spectrum, is supposed to be due to manganese. These lines are seen shortly after the commencement of the blowing, and brighten with the appearance of the sodium line, which becomes divided. Towards the end of the process, the second sodium line, and afterwards the bright lines, fade gradually. No particular observation is founded on the character of the carbon lines in the spectrum at any part of the operation.

The loss on the blow, amounting to about 10 per cent., is usually made up by the addition of scrap and waste steel, in quantity sufficient to bring back the weight to 5 tons. The heat of the bath is high enough to dissolve the solid masses added; but it is necessary to warm them before throwing them into the converter, more particularly in winter, when explosions sometimes take place if this precaution is neglected, probably from moisture or hoar-frost adhering to the surface.

The quality of the metal in the converter is tested by inserting an iron rod into the bath, and examining the crust of slag and the included shots of metal. The slag should be, externally, of a bright coffee-brown colour, and straw yellow on the fractured surface. The included shots of steel are tested by hammering upon a flat anvil, when they should flatten to round discs without showing signs of radial cracking. If such cracks are produced, the steel is too hard, and the blowing is continued until the necessary softening, determined by a repetition of the test, has been effected.

The casting is effected in the usual way into cast-iron ingot moulds, the weight of the ingots being about 9½ cwt. A test ingot 4 inches square and 6 inches long is taken from each charge, and subjected to the usual forge tests for bending and hardening, as well as for welding. For the latter purpose a portion of the test block, hammered to a flat bar and drawn taper at the ends, is doubled over and welded. The welded portion is bent double at a red heat, and flattened again. If it stands this treatment without showing cracks, the quality is satisfactory. The tensile strength is determined from time to time upon bars which are turned down from a square of 1·2 inch in the side to a cylinder of 0·51 inch in diameter. The average tensile strength of the steel used for rail-heads is about 38 tons per square inch, and the extension before fracture 30 per cent.

The average composition varies between the following limits:—

	Per cent.
Carbon	·25
Silicon	·20 to ·40
Manganese	·20 „ ·40
Phosphorus	·06 „ ·12

The quantity of manganese and silicon is remarkably large, and may be supposed to supplement the deficiency in carbon, which is not more than would qualify the steel as soft for making axles and machinery.

As soon as the ingots are removed from the moulds they are conveyed, while still at a red heat, to the heating furnace, where they are brought up to the proper temperature for hammering in about an hour and a half. Direct forging without re-heating has been tried, and found objectionable, owing to the cooling and consequent hardening of the outer crust of the ingot, while the interior was still sufficiently hot to work easily under the hammer, so that cracks formed on the outer skin, which could not be removed by any subsequent welding process. The re-heating takes place in a Siemens furnace. The ingots when at a bright red, not white, heat, are forged, under a 12½-ton hammer, to blocks of 8 inches square. These are subjected to a second heat, and then rolled off to slabs of the proper form for the tops of the rail piles. These are rectangular, 8·3 inches broad and 2·2 inches thick, with a projecting rib on the under side 1·2 inch broad and 1·4 inch thick.

In forming the piles a layer of puddle bars of a granular texture is placed below the top slab, so as to fill up the hollow on each side

of the projecting rib. Below this are two layers of puddle-bars of a more fibrous character, of the full width of 8·3 inches, forming the centre of the pile, while the two bottom layers consist of flattened crop ends or scrap bars, with an edge bar of good fibrous No. 2 iron at each corner, for forming the flanges. The total weight of the pile is 660 lbs. for a finished weight of 473 lbs., the loss on welding being 10 per cent. The disposition of the materials is as follows:—

	lbs.
Top slab, steel	253
Puddle bars	143
Re-worked iron, No. 2, including 198 lbs. of flattened crop ends	264
Total . . .	660

Of which two-fifths are steel and three-fifths iron.

The pile, when brought to the welding heat, is passed four times through the blooming rolls in order to unite the different elements, the loss on this operation being from 8 to 10 per cent., and the consumption of coal 47 per cent. of the original weight of the pile. The finishing heat requires a further quantity of 35 per cent. of coal, and causes a loss of 5 to 6 per cent. on the weight of the finished rails. The crop ends on rails of 473 lbs. weigh from 99 lbs. to 110 lbs.

The fracture of one of these rails shows a gradual passage from a long fibrous structure in the flange through a shorter fibre in the lower part of the web, to a granular texture in the upper part, the steel head being united to the granular cheeks by a central rib formed by the extension of the projecting rib on the slab. The fish-plate holes are best formed by drilling, but as the drilling of oval holes is a slow process, round holes are recommended.

Numerous trials upon crop ends of these rails have been made under a steam hammer, with a view to test the welding of the steel head with the iron web, but in only one case was any separation observed.

The Saxon Government have employed these rails to a considerable extent since 1869. The quality of the iron is reported on as not good, but the welding of the Bessemer steel with the iron is considered satisfactory.

Of the total number of fractures of steel-headed rails reported in 1873, 49·6 per cent. were through the fish bolt-holes.

The proportion of fracture was as follows:—

Of the rails laid down in	There were broken in the years 1871.	1872.	1873.
	Per cent.	Per cent.	Per cent.
1869	·0603	·0362	·0483
1870	·0067	·0137	·0117
1871	·0011	·0050	·0058
1872	..	·0057	·0228

These rails were supplied under a ten years' guarantee.

The Thuringian Railway Company report that the rails from the Marien Hütte stand well, and that no tendency to separation between the iron and the steel portions has been observed.

The production of these rails averages from 23,300 to 24,700 tons per annum.

H. B.

Elasticity of Railway Springs. By M. E. Belleroche.

(Annuaire de l'Ass. des Ing. sortis de l'Ecole de Liége, Jan. and Feb. 1875, pp. 1–12.)

The elasticity of a spring is the property of recovering its original shape after having been deflected. All work done in excess of certain limits of this elasticity results in a molecular alteration, which, after frequent repetitions, terminates in rupture. Flexibility is the measure of the deflection under a given strain, and should never exceed the limits of elasticity of the material, in this instance, steel. As the standard of flexibility, the Author takes the deflection under a load of 2,204·62 lbs., or, practically, of 1 ton; and adds that the flexibility of springs depends upon their mode of construction and upon the quality of the steel, while the limit of their elastic flexibility depends upon the temper which can be given to that metal.

In the following formulæ P expresses in pounds avoirdupois the load applied longitudinally per foot of length to a square bar, the length of whose side is 0·039 inch. A expresses in feet the elongation produced per foot of length upon the bar experimented upon. The co-efficient of elasticity is represented by E, and is the ratio of P to A. The load applied perpendicularly to the centre of the spring is measured by 2 Q, also in pounds. The number of plates in the spring is represented by N, and the number in one row by N_1. The breadth of the plates is given in feet by the symbol a, the thickness by e, and the length of the first plate between the points of support by 2 L, all in the same unit. I is also in feet, and measures the amount of the central deflection of the spring under a load Q. The moment of elasticity is represented by M, and is equal to $E \frac{a e^3}{12}$.

In a plain bar, the elasticity is measured by the maximum value which can be given to A without causing the value of E to vary in the formula $\frac{P}{E} = A$. The flexibility of a spring is calculated by the equation

$$\frac{Q \times 12}{6 N \times E a e^3} \left\{ 2 L^3 + \left(\frac{N_1 L}{N} \right)^3 \right\};$$

or, substituting M for $\frac{E a e^3}{12}$,

then $$\frac{Q}{6 N \times M} \left\{ 2 L^3 + \left(\frac{N_1 L}{N} \right)^3 \right\} = I.$$

The elongation produced at the centre of the principal plate within the limit of elasticity is given by the formula

$$A = \frac{12\, e\, Q\, L}{2\, N\, E\, a\, e^3};$$

and making the same substitution as in the previous equation,

$$A = \frac{e\, Q\, L}{2\, N \times M}.$$

When A exceeds a certain value, the extension is no longer proportional to the load, and consequently the value of E varies; but so long as the disproportionate extensions do not exceed certain limits, the elasticity of the steel is not sensibly affected. The value of the co-efficient E depends upon the quality of the metal, the maximum elastic value of A upon the temper. The quality of the steel becomes improved, first, by a higher value of E, and, secondly, by an enlargement of the limits of the elastic extension produced by tempering, so long as the steel is not rendered brittle. In the work which springs have to do, the two factors E and A play the principal part. It is to their measurement and verification that the greatest importance should be attached, and any divergence from their assigned values should be determined within the narrowest limits. The value of E for ordinary suspended springs of steel is 20,000, and for A 0·005. Practically, A should not exceed 0·004, and it is the maximum value which is of the greatest consequence, since that represents the extent to which the spring can be deflected, without causing any alteration in the steel. If a bar of steel, having a thickness equal to e, be bent to a radius R, it will, by virtue of its flattening, undergo an elongation which is given by the formula

$$A = \frac{e}{2\, R};\ \text{if } R = 100\, e, \text{ then } A = 0\cdot 195''.$$

In making practical experiments upon the plates of steel springs, the Authors suggest the following mode of proceeding:—Take out the plates and soften them, bend them to a radius which is equal to one hundred times their thickness, retemper them, and submit them twice to the flattening test. A permanent deflection of 0·039 inch may be allowed for the first trial, but the second ought to produce none, the plates returning precisely to the same form; that is, to the curve they assumed after the first test.

In order to facilitate the experiments, the length of the plates should not exceed about 2 feet 6 inches. If these tests are satisfactory, and it is also ascertained that the average flexibility of the springs is equal to that given by the equation E = 20,000, it may be safely concluded that the steel is of a quality sufficiently good to fulfil the required conditions of elasticity. All newly-made springs, on being tested, suffer an appreciable flattening, due to their con-

struction. The proper trials to be relied upon are those undertaken after the springs have attained their permanent or working flexibility. Particular attention should be paid to the value of e. Given two springs, differing only in the thickness of the plates, the relation between their relative flexibility is expressed by the formula

$$I = I_1 K \frac{e_1^3}{e^3},$$

showing that their flexibility is in the inverse ratio of the cube of the thickness of the plates. It should, therefore, be specified that a bar of given length should not be less than a certain prescribed minimum weight. Moreover, in laying down rules for the loads of different springs, the minimum weights, together with the maximum and minimum flexibilities, should be so many data; and in the tests the values of E, A, and e should be rigorously verified.

The Author found that the results of his experiments agreed with the formulæ in all instances in which the thickness of the plates was originally the same, and, after the first test, somewhat less. The thickness of the plates is of such importance that the slightest difference in the weight of a foot length causes a serious discrepancy between theory and practice. M. Belleroche concludes that the formulæ are sufficiently exact for practical purposes, that the conditions laid down can be rigidly adhered to, and that steel of the proper quality can be procured without difficulty or extra price.

T. C.

New Counter-Pressure and Vacuum Break.

(Revue Industrielle, 2 June, 1875, p. 194.)

The well-known Le Chatelier counter-pressure break forms the basis from which the following one has been devised, for the purpose of overcoming certain defects stated by the inventor, M. Harmignies, to attach to that break, and which he asserts are the cause of overheating and cutting of the pistons, cylinder slide valves and slide faces, carbonisation of the packing, and the issue of pulverised water from the chimney. These defects are said to be overcome by the following means:—

The casting, forming the junction of the two exhaust pipes from the cylinders, is provided, above its bifurcation and near the junction with the exhaust pipe which passes up to the chimney, with a flat valve seat, carrying a slide valve with an elongated semicircular-ended aperture to one side of its figure, covered by a smaller flap valve hinged to the former, and pressed down upon it by a flat spring, allowing a small range of upward angular

movement. A rectilinear motion is given to these valves in a direction transverse to the centre line of the engine by levers connected with the engine regulator. Coupled to one of these levers is a connecting rod, giving motion to a small cock conveying water from the tender into the exhaust junction pipe a little below the slide valve, where it is placed. These parts are arranged so that, when steam is turned on at the regulator, the small jet of cold water is turned off, and the slide valve above described, with the small one upon its upper side, is at the same time moved from over the exhaust exit into a chamber provided for its reception, leaving the exhaust pipe clear. When the steam is shut off the reverse operations take place; the exhaust exit is covered over, and a small jet of water admitted into the cylinders causing alternate vacuum and pressure therein, any excess of the latter being provided against by the small valve already noticed.

The experiments with this break proved entirely successful. They were made on the Dombes railway, under M. Jouffret, who has improved the designs submitted by M. Harmignies, and who found that on a gradient upon which the Le Châtelier break was unable to hold a train 120 tons in weight, the Harmignies break stopped a train 139 tons in weight in 437·5 yards.

The experiments also proved that—

1. The break was more prompt than the Le Chatelier.
2. Less heating of the cylinders, &c., took place.
3. The wear and tear were less.
4. The injection being admitted automatically, and without the exercise of judgment on the part of the engine-driver, the break was rendered as efficient by night or in rain as by day.
5. No ashes or gaseous products of combustion can be drawn down into the cylinders or steam chests.
6. Passengers or by-standers are not inconvenienced.
7. The men do not object to this break, as they do to the Le Chatelier break.

It is pointed out that most of these results can be obtained with the Le Chatelier break; but to do so, great care and judgment are necessary.

W. W. B.

On the Resistance offered by Straight-linked Chains to a Sudden Shock. By H. Resal.

(Journal des Mathématiques Purs et Appliquées, Feb. 1875, pp. 43–56.)

This Paper, though consisting chiefly of an abstract mathematical investigation, has an important practical object in demonstrating the uselessness of the so-called 'safety chains,' which have been extensively employed in the coupling of railway wagons.

When calculating the section of a chain, the practice is to treat it as equivalent to two parallel rods, each having the diameter of the chain, assuming the strain to be uniform over the whole section of the link. M. Resal showed this to be erroneous as early as 1862; it is clear, in fact, that the circular end of the link is acted on by a transverse strain like a girder, and therefore partly in tension, partly in compression. The surmise that this inequality of strain extends also to the straight sides of the link is proved by M. Resal in a complete discussion of the equations of resistance for any plane section of the link taken at right angles to its axis. At the point where the curve of the link begins, or, as it may be called, the 'springing' of the circular part, he finds the maximum tension to be at the *inside*, so that the link tends to open from the inside at this part.

It follows from this that if the section of the link be fixed on the supposition of equal strain throughout, the tension at the inside will be greater than the assumed working tension; the amount of this maximum tension will depend upon the ratio which the radius of the chain iron bears to that of the circular end of the link. The Author gives a formula for determining this ratio, so that the proper working tension may not be exceeded. He investigates the amount of molecular work done upon a link to produce a given small deformation in the circular ends, and calculates the greatest tension per square inch which will thus be produced anywhere within the link.

These results are applied to the question of safety chains in railway carriages and wagons. Suppose a draw-bar breaks in the middle of a train. The wagons in front immediately move more quickly, owing to the diminished resistance to the traction of the engine. Those behind move more slowly, and the train splits at the point of rupture, rapidly tightens up and brings a strain upon the safety chains. The effect of this sudden strain is to transform a part of the *vis viva* of the train into work done by the deformation of the links of the chains.

M. Resal finds in the usual manner an expression for the *vis viva* lost, and this gives the amount of work done upon the chains. But from his previous investigation it is possible to ascertain the greatest tensile strain which will be produced anywhere within the link by a given amount of work of deformation done upon it. Hence it is easy to determine the maximum strain produced upon the links of the chain by the shock due to their sudden tightening up.

Having thus completed the theory, M. Resal applies it to actual practice, taking for example a standard train of the Paris and Lyons railway. This consists of a locomotive weighing 32 tons, a tender weighing 22 tons, and a train of wagons each weighing 9 tons. The speed is taken at 20 miles an hour, and the safety chains are of $\frac{7}{8}$-inch iron, with a radius of link $1\frac{3}{8}$ inch. The greatest possible weight of such a train is taken at 636 tons. In this case the formula shows that if the draw gear uniting the

sixth to the seventh wagon from the hinder end should break, the resulting shock would also break the safety chains, even if made of the best charcoal iron.

W. R. B.

On the Purification of Feed Water for Locomotives on the Thuringian Railway.

(Organ für die Fortschritte des Eisenbahnwesens, vol. xi., part 5 & 6, pp. 221–223.)

The extensive development of limestones and gypseous rocks along the Thuringian lines of railway has been a source of considerable difficulty, owing to the hardness of the feed water, from the presence of gypsum and carbonates of lime and magnesia, which produced a rapid deposit in the locomotive boilers. An experiment to soften such water by the addition of carbonate of soda and caustic lime, so as to precipitate the lime as carbonate, leaving sulphate of soda in solution, gave unsatisfactory results. Another plan, suggested by Dr. De Haën, of Hanover, which has been used with success for a year, consists in adding chloride of barium and caustic lime, whereby sulphate of baryta and carbonates of lime and magnesia are precipitated, chlorides of calcium and magnesia remaining in solution. These salts are not injurious to the boiler, if the solution is not concentrated above a density of 10° Beaumé; and the earthy carbonates and sulphates being removed, no deposit can take place. The process is carried out in the following manner:—The water to be purified is received in settling tanks to three-fourths of their height, and the necessary amount of chloride of barium dissolved in warm water is added, and distributed by stirring; caustic lime is then added and stirred in until the precipitate forms in flocks, and the water has a slight alkaline reaction. The tank is then filled and gently stirred, when the precipitate is allowed to settle, which requires from ten to fifteen minutes. The precipitation is facilitated by heating the water with exhaust steam to 99·5° or 110·75° Fahr.

The rapid clearing of the water is due to the mechanical action of the carbonate of lime, which separates into comparatively large particles and carries down the exceedingly fine precipitate of sulphate of baryta, which if alone would require several days for complete subsidence. This property is so well appreciated by the workmen in charge of the process, that it is necessary to test the purified water as to its alkaline reaction, to prevent the use of an excess of lime. The separation of the suspended sulphate of baryta is also facilitated by allowing the precipitate formed in the operation to remain in the tank, and by stirring it up with the water after the next addition of the precipitating reagents.

The following results have been obtained by the use of this process. At the Erfurt station, where the daily consumption of water is about 52,000 gallons, the purification is effected in four settling

tanks of 300 cubic feet, and four storage tanks of the same size. The impure water contains—

Bicarbonate of lime	0·0025	per cent.
" " magnesia	0·0005	"
Sulphate of lime	0·0023	"
Fixed impurities capable of forming deposits	0·0053	"

The proportion of chemicals added is—

Chloride of barium	0·0083	per cent.
Caustic lime	0·0016	"

The barium solution is added in the proportion of 16·5 lbs. of an 80° solution, with 7·25 lbs. of lime cream to each tank.

The analysis of the softened water is as follows:

Lime in excess	0·0007	per cent.
Chloride of calcium	0·0032	"

the carbonate and sulphate of lime being entirely removed.

At Weissenfels station the daily consumption is from 10,000 to 11,000 cubic feet of water. It contains—

Bicarbonate of lime	0·0025	per cent.
Sulphate of lime	0·0031	"

The purification requires—

Chloride of barium	0·0103	per cent.
Caustic lime	0·0021	"

The purified water contains—

Chloride of calcium	0·0030	per cent.
Lime in excess	0·0008	"
Carbonate and sulphate of lime	none	

No inconvenience has been experienced from the chloride of calcium or the small excess of lime in the boilers of the locomotives. The cost of this process is—

	s.	d.	
At Erfurt	6	8	per 1,000 cubic feet.
" Weissenfels . . .	7	4	" "

The higher cost at the latter place is due to the large quantity of gypsum in the water, namely, 3 parts in 1,000. At Apolda station, where the gypsum amounts only to 0·0002 per cent., the cost for chemicals is only 6*d.* per 1,000 cubic feet.

H. B.

On the Efficiency of Coating for Steam Pipes.

By B. F. Isherwood.

(Journal of the Franklin Institute, March 1875, pp. 187–197.)

In this Paper, Mr. Isherwood discusses some experiments on the efficiency of several kinds of coating in preventing the loss of heat by radiation from the surfaces of steam pipes, an account of which was communicated by M. Burnat to the Société Industrielle de Mulhouse in 1859.

The experimental apparatus consisted of five parallel groups of cast-iron pipes; each group contained four pipes 4·72 inches in diameter externally, and ¼ inch thick, an aggregate surface of 58·47 square feet being exposed for each group. The groups were placed at distances apart of 39·37 inches, and were inclined at an angle of 1 in 20. They were severally connected at the higher ends with a steam pipe from the same boiler, and drained into separate tanks at the lower ends. The apparatus was placed in a large unheated hall free from air currents.

Four of the groups of pipes were coated, the pipes of one group having been allowed to remain in their natural condition as they left the foundry, thus:—First group: covered with straw laid lengthwise to the thickness of 0·6 inch, bound with straw rope wound closely round it. Second group: left bare. Third group: each pipe laid in a pottery pipe, with an air-space between the two, and coated with a mixture of loamy earth and chopped straw, covered with tresses of straw. Fourth group: covered with cotton waste to a thickness of 1 inch, wrapped in cloth bound with string. Fifth group: coated with a composition of clay and cow's hair to a thickness of 2·36 inches. Finally, trials were made with the second group of pipes by coating them with some old felt which had been treated with caoutchouc; and a second trial of the fifth group, after the composition had received a coat of white paint.

A preliminary trial was made with all the groups of pipes bare, when it was found that the variation from the average rate of condensation within the several groups did not exceed ⅝ per cent., proving the uniformity of the conditions under which they were placed. The pipes were then coated, and trials made with steam of successively increasing pressures of from 1⅛ to 2 atmospheres, or from 16½ lbs. to 30 lbs. absolute pressure per square inch. The experiments lasted from forty to fifty-six minutes for each pressure of steam applied; and an abstract of the results is furnished in the table on the next page.

When the plaster coat of the fifth group was painted white, an average of 0·307 lb. of steam was condensed per square foot of pipe per hour; and the second group, with the felt coating, condensed 0·313 lb. of steam per square foot per hour.

From these data, Mr. Isherwood, assuming that the rate of

RESULTS of EXPERIMENTS on the CONDENSATION of STEAM in PIPES.

Absolute Pressure of Steam per Square Inch.	Temperatures.			Steam condensed per Hour per Square Foot of External Surface of Pipes, in the several Groups of Pipes.				
	Steam.	Air.	Difference.	1st. (Straw Coat.)	2nd. (Bare.)	3rd. (Pottery Coat.)	4th. (Waste Coat.)	5th. (Plaster Coat.)
lbs.	°	°	°	lb.	lb.	lb.	lb.	lb.
16·5	218·0	46·4	171·6	·139	·496	·170	·217	·254
16·5	218·0	33·8	184·2	·152	·485	·166	·205	·262
18·4	223·4	33·7	189·7	·164	·555	·186	·229	·287
18·4	223·4	27·1	196·4	·182	·571	·264	·287	·344
22·0	233·2	41·5	191·7	·246	·576	·254	·244	·320
22·0	233·2	36·5	196·7	·164	..	·158	·250	..
22·0	233·2	36·1	197·1	·162	·557	·178	·260	..
22·0	233·2	28·9	204·3	·201	·586	·264	·328	·346
25·7	241·6	43·3	198·4	·244	·645	·301	·375	·389
25·7	241·6	36·5	205·1	·274	..	·285	·369	..
29·4	249·1	43·3	205·8	·252	·721	·270	·342	·379
29·4	249·1	30·6	218·4	·225	·621	·250	·328	·336
Averages 22·0	233·1	36·5	196·6	·200	·581	·229	·286	·324

condensation in still air is in the ratio of the difference of temperature for each group, deduces the following constants for an absolute pressure of steam of about 22 lbs. per square inch; for the quantity of steam condensed, and the quantity of heat radiated per square foot of external surface of pipe per hour for 1° Fahr. difference of temperature:—

	Steam condensed.	Heat radiated.
	Pound.	Units.
Bare or uncovered pipe	·00302	2·875
Coated with straw	·00101	0·962
Cased in pottery pipes, with air-space	·00116	1·106
Coated with cotton waste, 1 inch thick	·00146	1·383
Coated with old felt	·00156	1·478
Coated with plaster of loamy earth and hair . . .	·00166	1·575
The same, painted white.	·00154	1·460

Mr. Isherwood takes occasion to remark that a material gain can be realised by discharging from the steam pipe of an engine direct into the steam jacket rather than into the cylinder, since in the former case the condensed steam ejected from the pipe is returned to the boiler at the temperature, undiminished, of the steam; whilst, in the latter event, the water is cooled down to the temperature of the hot well.

D. K. C.

Report of Trials of the Steam Machinery of the United States Revenue Steamers "Rush," "Dexter," and "Dallas."

By Charles E. Emery.

(Journal of the Franklin Institute, March 1875, pp. 197–203.)

The three new steamers, the "Rush," the "Dexter," and the "Dallas," completed in 1874 for the United States Marine, represent the smallest type of full-powered screw cutters for cruising purposes. They are similar as to hull, screw, and boilers; but the engines differ from each other, that of the "Rush" being a compound receiver-engine, that of the "Dexter" a high-pressure condensing engine, and that of the "Dallas" a low-pressure condensing engine.

The hulls are of wood, 140 feet long over all, 129½ feet between perpendiculars at water-line, with 23 feet beam, and 10 feet depth of hold; draught, 8 feet 10 inches aft. The screws are 8 feet 9 inches in diameter, with an average pitch of 14½ feet. The speeds of the vessels on their trial trips averaged from 10 to 11 knots per hour. Each vessel has one boiler, with a double segmental shell. The boiler has three furnaces, with a total grate-area of 57 square feet; in the "Dallas," the boiler has one hundred and sixty flue tubes, 3¼ inches in diameter, 9 feet 3 inches long; and in the two other vessels, one hundred and fifty-eight flue tubes, 3¼ inches in diameter, by 9 feet 8 inches in length. The gross area of heating surface is

In the "Rush" boiler .	1,572·85 square feet	= 27·58 times the grate-area.	
" "Dexter" " .	1,572·85 "	= 27·58 "	"
" "Dallas" " .	1,689·24 "	= 29·63[1] "	"

The compound engine of the "Rush" has vertical cylinders 24 inches and 38 inches in diameter, with a stroke of 27 inches, thoroughly steam-jacketed, felted, and lagged, and connected to cranks at right angles. The single cylinder of the "Dexter" is inverted, being 26 inches in diameter, with a stroke of 36 inches, and carefully felted and lagged. The cylinder of the "Dallas" is also inverted, 36 inches in diameter, with a stroke of 30 inches. The steam is cut off in each engine by short slide-valves, with adjustable plates. The surface-condensers are worked with centrifugal circulating pumps. The total volume of the clearance and passages for each end of the cylinder, in parts of the working capacity of the cylinder, was as follows:—

"Rush"	1st cylinder .	7·89 per cent.
	2nd " .	5·85 "
"Dexter".		5·37 "
"Dallas"		8·02 "

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[1] Printed, by mistake, 49·63.

The engines and boilers were new and in good order at the time the trials were made, and every precaution was taken to insure accuracy of results.

Fourteen comparative trials were undertaken during the month of August 1874, of which two were made of the engines of the "Rush," seven with those of the "Dexter," and five with those of the "Dallas." The trials were carried out with the vessels secured to the wharf.

The average temperatures of air and water were as follows:—

	"Rush."	"Dexter."	"Dallas."
External air	66°·1 Fahr.	66°·0 Fahr.	71°·7 Fahr.
Engine-room	86°·0 "	83°·3 "	78°·1 "
Sea-water	59°·8 "	66°·0 "	67°·6 "

The leading results of the trials are as follows:—

	"Rush." 1st trial.	"Rush." 2nd trial.	"Dexter." 1st trial.	"Dexter." 7th trial.	"Dallas." 1st trial.	"Dallas." 5th trial.
Average cut-off—						
1st cyl.	·36	·60	·18	·45	·13	·39
2nd "	·46	·53				
Average ratio of expansion—						
1st cyl.	2·46	1·60	4·46	2·08	5·07	2·32
both	6·22	4·03				
Average total initial pressure in cylinder per square inch—						
1st cyl.	82·3 lbs.	50·2 lbs.	80·4 lbs.	53·6 lbs.	46·9 lbs.	39·4 lbs.
2nd "	23·5 "	22·0 "				
Average total terminal pressure per square inch—						
1st cyl.	29·4 lbs.	27·9 lbs.	15·3 lbs.	19·0 lbs.	9·5 lbs.	14·8 lbs.
2nd "	9·2 "	9·2 "				
Average effective mean pressure—						
1st cyl.	29·7 lbs.	18·9 lbs.	34·4 lbs.	33·8 lbs.	18·5 lbs.	24·1 lbs.
2nd "	12·7 "	12·3 "				
Revolutions per minute—	70·8	55·5	56·5	60·7	48·7	63·5
Indicator HP.—						
1st cyl.	127·9	63·7	185·9	196·2	138·0	234·3
both	266·5	168·7				
Water used per indicator HP. from tanks—	18·4 lbs.	22·1 lbs.	23·9 lbs.	31·8 lbs.	26·7 lbs.	31·0 lbs.
Water used per indicator HP. according to indicator-diagram—						
1st cyl.	17·1 lbs.	19·7 lbs.	16·2 lbs.	20·3 lbs.	19·2 lbs.	22·8 lbs.
2nd "	13·5 "	16·9 "				

The chief results of the most economical performances respectively are as follows:—

Averages.		"Rush."	"Dexter."	"Dallas."
Ratio of expansion . . .	1st cyl. both	2·46 6·22	3·49	3·13
Effective mean pressure. .	1st cyl. 2nd "	29·7 lbs. 12·7 "	42·0 lbs.	23·5 lbs.
Revolutions per minute . .	. . .	70·8	72·8	61·5
Indicator HP.	1st cyl. both	127·9 266·5	292·4	221·4
Water per indicator HP. from tanks	..	18·4 lbs.	23·9 lbs.	26·9 lbs.
Water per indicator HP. per indicator-diagrams . . .	1st cyl. 2nd "	17·1 lbs. 13·5 "	16·3 lbs.	20·1 lbs.
Coal consumed per indicator HP. per hour	..	2·44 lbs.	3·13 lbs.	3·43 lbs.
Water evaporated per lb. of coal at observed temperatures	..	7·55 lbs.	7·63 lbs.	7·86 lbs.
Equivalent evaporation from 212°	..	10·84 lbs.	10·90 lbs.	11·02 lbs.

If boilers had been used, so proportioned as to evaporate 9 lbs. of water per pound of coal, the "Rush" would have consumed 2·04 lbs. of coal per indicator HP.

The report is illustrated with indicator-diagrams.

D. K. C.

Researches on Ebullition. By M. Desiré Gernez.

(Annales de Chimie et de Physique, March 1875, pp. 335–401.)

After having first reviewed the history of researches on ebullition, the Author proceeds to describe his own experiments, in the cases of liquids heated in contact with solids, and of liquids heated in contact with other liquids, whence he deduces the theory of ebullition, and considers lastly the action of mechanical force on the phenomenon.

Liquids heated in contact with Solids.—When heating a liquid above the normal point of ebullition, ebullition is accompanied with explosion. In his experiments the Author used cylindrical glass vessels, washed perfectly clean with sulphuric acid, and closed at one end. The liquid he employed was pure and free from solid matter: it should be poured into the tube so as not to imprison any air, and ought to be heated in water or paraffin baths, as, in consequence of the bad conducting qualities of glass, a naked flame might heat a portion of the fluid to a higher temperature than it can endure. He was careful not to produce vibrations. The following conclusions were arrived at:—

1. Solid bodies which cause boiling of superheated liquids lose that property when highly heated. When certain portions of

platinum wire, heated either in closed glass tubes or by means of an electric current, are immersed in a liquid, the heated portions remain inactive.

2. Solid bodies without chemical action on superheated liquids cease to produce bubbles of vapour after having caused boiling for a longer or shorter period. If a piece of stearine be inclosed in a bell-shaped glass vessel, attached to a glass tube, shut at its upper end, and introduced into water heated to boiling, bubbles will not rise after the first few minutes, even if there be air above the stearine. Let a piece of spongy platinum be made white hot, and put into boiling water for five minutes; let boiling be suspended for five minutes, and let this action be repeated. After a time water above 212° Fahr. will not produce a single bubble with the platinum.

3. A body, the surface of which has not been in contact with air, or which does not contain air or gas, has no effect on superheated liquids. Introduce a glass tear into a thick glass vessel, the water in which is kept boiling until no bubbles come from the tear. Let the water cool and break the point of the tear. The result is an explosion which reduces the tear to powder; but though the water be again superheated, the glass fragments will not cause boiling.

4. Solid bodies rendered inactive, by remaining in a boiling liquid, or through the influence of heat, become active again on exposure to the air. If a platinum wire which has been rendered inactive by its presence in boiling water be carefully removed, so as not to be exposed to dust, and again replaced in the liquid, it will reproduce boiling.

5. A gaseous atmosphere causes the boiling of superheated liquids. Introduce into a superheated liquid a small bubble of air by means of a tube with a bell-shaped mouth closed at its upper extremity, and the liquid will immediately boil. When the mouth of the bell is covered with wire gauze, bubbles are formed where the pressure is least; and it is found that the effect of a single bubble of air is continuous.

Explanation of the Phenomenon of Ebullition.—Place a liquid in a perfectly clean tube, raise the temperature at the surface of the liquid: vapour will be produced with a maximum tension corresponding to the temperature, or an inferior one, as the space is limited or unlimited: by raising the temperature the tension will become equal to the atmospheric pressure, when boiling will be possible, if there is a gaseous bubble in the liquid. Next the volume v being the volume under the atmospheric pressure P, the new volume will be unlimited when the maximum tension of the vapour is equal to P, being then $\frac{v\,P}{P\text{-}P}$. On the other hand, ebullition can be retarded to the temperature of the total evaporation of the liquid, or to a temperature approaching that at which, in the experiment of Cagniard de Latour, the liquid becomes expanded to vapour.

The Author then discusses the mechanism of ebullition, and shows that—

1. Ebullition is an evaporation at the surface of the introduced gases.
2. An infinitely small quantity of gas suffices to produce unlimited boiling.
3. Each bubble of vapour is formed at the expense of a certain quantity of air.
4. A bubble of vapour on quitting the orifice of a tube leaves a very small bubble behind which continues to sustain ebullition.
5. Bodies which are not wetted by liquids produce ebullition, because the liquid is kept at a distance, and the dissolved air will gather in the spaces.
6. A diminution of pressure will allow the liquid to be superheated, because the diminution takes place slowly, and the dissolved gas is disengaged at the free surface of the liquid, thus allowing an elevation of temperature without the production of gaseous bubbles.

Liquids completely surrounded by other Liquids.—A drop of water introduced into a mixture of essence of cloves and linseed oil can be slowly superheated, and if free of gas will remain liquid up to the temperature of total evaporation. If it contain air, the elevation of temperature will produce a supersaturated solution, and will retain the dissolved air up to this limit; but in the assumed case the dissolved gas will diffuse into the surrounding liquid. Thus by slow heating the water will attain higher and higher temperatures without boiling.

Ebullition produced by Mechanical Action.—If a rod be rubbed briskly along the surface of a vessel containing a superheated liquid, boiling will be at once produced, the action producing bubbles of gas, which were in the state of a supersaturated solution.

The Author gives the following applications of the theory of boiling.

Normal boiling point.—It being very easy to superheat liquids, some difficulty has been found in obtaining the normal point of ebullition: this can be easily remedied by the introduction of a bubble of air, or the employment of porous substances not acting chemically on the liquid.

Starts.—If a porous substance has been employed to produce normal boiling as described, and if the liquid is cooled and again heated, it boils with starts, owing to the capillary channels having lost the greater portion of their air; the liquid contained in them can be superheated, until a bubble of air coming from the interior portion causes the sudden formation of a large quantity of vapour. This action can be avoided by the employment of substances which by their action on the liquids produce even small quantities of gas, such as spongy platinum, and zinc and iron for water.

Explosions of steam boilers by the sudden expansion of vapour in superheated liquid.—The fact that explosions frequently occur on renewing work, when the water has been maintained without external

expenditure of vapour at a temperature little inferior to that of boiling, leads to the opinion that the cause lies in the sudden expansion of vapour in the superheated liquid. A piece of coke, or the introduction of a solid substance with the fresh water, which will produce a bubble of vapour in the superheated liquid, would cause an explosion. A piece of metal, such as zinc, maintained in the boiler would obviate such results.

E. B.

On the Siemens Gas Furnace. By M. G. Boistel.

(Mémoires de la Société des Ingénieurs Civils, April 16, 1875.)

This is mainly a comparison between the Siemens gas furnace and the Ponsard gas furnace, in reply to a communication on the Ponsard furnace made to the Société by M. Périssé in October 1874.[1] M. Boistel points out that in the Siemens furnace, in which the air and the gas are both heated by the burned gases passing down to the chimney flue, the waste heat is more completely utilised than it can be in the ordinary Ponsard furnace, in which the waste flame is made use of to heat the air alone, as in the latter the volume of air passing up through the regenerator is insufficient to take up the whole of the heat contained in the waste gases, which thus pass away to the chimney at a high temperature, about 1113° Fahr. M. Ponsard has proposed to utilise this heat by supplying the gas-producer, as well as the furnace itself, with hot air from the regenerator; but it is to be feared that the working of such hot-blast gas-producers will be difficult.

The reversing of the flame in the Siemens system presents no difficulty, but, on the contrary, serves to render the heat more uniform throughout the extent of a large furnace, such as the furnaces for melting plate glass, which are more than 36 feet long inside, and the large heating furnaces at Ebbw Vale, which are 19·7 feet long, and heat 72 tons of Bessemer ingots in twenty-four hours, with a consumption of coal not exceeding 275 lbs. per ton. The regenerator of the Ponsard furnace, in which the air and the waste flame pass in opposite directions through alternate flues, is very subject to leakage, and, as it acts only by the transmission of heat through walls of badly-conducting material, it is at best less effective than the Siemens arrangement. The remainder of the Paper is a sketch of the applications of the Siemens furnace to puddling and to open-hearth steel-making.

In the discussion that followed, M. Périssé spoke at some length in defence of the Ponsard system. He stated that the joints between the bricks of the regenerator (or récupérateur, as he terms it) did

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[1] A Paper by M. Périssé on the Ponsard furnace, with drawings, was also published in the Annales Industrielles, Feb. 14, 1875. (Min. of Proc. Inst. C.E., vol. xl. p. 330.)

not leak if the apparatus had been properly built, even after long use and frequent stopping and re-lighting of the furnace. This was shown, on the one hand, by the fact that samples of the smoke or burned gases had, by analysis, the same composition, whether taken from the top or from the bottom of the regenerator; and on the other, by examining the regenerators of furnaces that had been let out, after having been long in work. In reply to the remark, that the efficiency of the Ponsard regenerator could not be great, on account of the low conducting power of fire-brick, he expressed the opinion, based on the results of the practical working of the furnaces, that the conducting power of fire-brick is much greater at high furnace heats than at ordinary temperatures. In conclusion, M. Périssé gave the particulars of the amount of work done in several furnaces on the Ponsard plan, and of the fuel consumed, and claimed for this system as great an economy of fuel and as little waste by oxidation of the substances heated as in the Siemens furnace.

W. H.

On Improvements in Gas Furnaces.

(Oest. Zeitschrift für Berg und Hüttenwesen, Feb. 22, 1875, pp. 75–78.)

The improvements noticed in this Paper are Wittenström's modification of the Siemens furnace, and Björklund's surface condenser, as applied to Lundin's system of gas-producer.

The chief novelty in Wittenström's furnace is the position of the regenerators, which are placed above the working bed, instead of the ordinary arrangement of masonry chambers below the floor-level. Each pair of regenerators forms a rectangular block above the admission passages and burners to the furnace, the two systems being united by a longitudinal flue, carried on an arch above the bed of the furnace, which is in communication with a central tube containing the reversing valves. These resemble the slide valves of a steam-engine, and are moved by chain and pulley purchases instead of by levers. The admission passages for gas and air are divided by fire-bricks into six rectangular channels, with a view to facilitate the mixture of the two currents before ignition, so as to obtain perfect combustion. Among the advantages claimed for the furnace are saving in cost of construction, no excavation for regenerators being necessary, ease in repairing and replacing bricks, and diminished wear in the regenerator bricks, as, the current of spent gases having to rise, there is time for any particles of slag carried forward to be deposited in the end flues, and they are not carried into the regenerator, as is the case when a downward current is used. Against this must be placed the less perfect retention of heat, owing to radiation from the surface of the wall exposed to the air, and consequent annoyance to the men working the furnace from the heat so lost. This is obviated by

the use of a double wall or air-jacket, the air passing through the space between before being admitted to the regenerator. The gases passing out at the top of the regenerator are sufficiently cooled not to require a special chimney to carry them away. The furnace described has a bed 5 feet 3 inches long, and is used for re-heating heavy piles for plates and Bessemer ingots.

Björklund's arrangement is designed to meet a difficulty in connection with Lundin's system of gas firing, in which the gas produced from the combustion of green wood, wet sawdust, &c., is enriched up to a proper burning condition by condensing the admixed steam with a jet of water—a method which, although efficacious, is attended with the production of a large quantity of waste water fouled with tar and other products of distillation. The admission of such water into the rivers is forbidden by the 40th paragraph of the general regulations for the erection of mining and smelting works in Sweden; and, in order to meet this prohibition, the arrangement to be described has been adopted at the Skultuna copper-works. The gas-generator is a circular stack closed at the top with the ordinary Siemens feeding valve. The gas is conducted through a cooling tube into a chamber, where the oily products of distillation separate. It then rises by a similar tube to the top of the condenser—a vertical cylinder filled with brass tubes cooled by the external contact of water, which is admitted below and passes out heated at the top. The steam mixed with the gas is condensed in passing down the cooled tubes, and is deposited as tarry water in a chamber at the bottom, while the dried gas passes through another rising pipe to the furnace. The condensing chambers discharge their contents into the well of an elevator, which is put in motion by a small water-wheel driven by the water discharged from the condenser. The tarry water is removed and conducted through a feed-pipe into a retort built into the bottom of the gas-producer, where the water is driven off by boiling. There are two retorts in each generator, so that the process can go on continuously. The effective sectional area of the generator at Skultuna is 160·59 feet; the section at the bottom is 3 feet. The gas serves two furnaces, one a pot melting furnace containing six pots of 90 lbs., and the other a refining furnace taking charges of 902 lbs. to 1,100 lbs. The consumption of fuel is about 63·6 cubic feet per hour of mixed materials, consisting of $\frac{1}{3}$ split wood, $\frac{1}{3}$ peat, and $\frac{1}{3}$ twigs, bark, and fir-cones. The condenser has sixty-one brass tubes of 1·8 inch internal diameter and 9·8 feet long. The consumption of water is from 88 to 130 gallons per minute. When used, as originally designed, for the supply of only one furnace, the temperature of the water discharged from the condenser was not above 41° Fahr., but since the second furnace has been added the temperature has reached 59° to 68° Fahr. The resulting gas is very pure. Two large producers on the same principle have also been adopted for annealing purposes; in these the consumption of fuel is only 46 cubic feet per hour, owing to the lower tempera-

ture required. The saving of fuel by this method of condensing has been found by experiment to be about 25 per cent. below that required when Lundin's principle of condensing by injection was used.

H. B.

New Processes in Proximate Gas-Analysis.

By Professor Henry Wurtz, New York.

(Journal of the Franklin Institute, February, March, and April, 1875, 12 pp.)

Insisting on the difficulties with which the eudiometric methods of analysis are surrounded, and commenting on the special and complex devices for lessening certain difficulties, Mr. Wurtz prefers to abandon methods which are purely volumetric, and to devise such others as would enable one to deal with quantities that can yield ponderable products, thus appealing directly to that infallible criterion, the balance.

The methods put forward by Mr. Wurtz are founded on the general principle of submitting a slow current of the gas to be investigated to the action of a series of agents, so selected and combined as to absorb and separate in succession, each by itself, the different proximate constituents of a gaseous mixture, converting each into a solid or a liquid, to be weighed in a balance. Confining his attention in the present Paper to illuminating gases, he enumerates the following constituents of crude coal gas as drawn from the hydraulic main:—1. Tar suspended in the form of spray; 2. Water as spray; 3. Water as vapour; 4. Naphthaline, condensable; 5. Other condensable hydrocarbons; 6. Smoke and soot, with dust; 7. Ammonia; 8. Carbonic acid; 9. Sulphuretted hydrogen; 10. Carbonic oxide; 11. Oxygen; that is, intermixed air. The first operation is the arresting of suspended matter by means of empty dry flasks, and straining through cotton previously desiccated; the second is the absorption of the ammonia by agents which do not act on any other ingredient. Fused potassic bisulphate is employed for this purpose. Next, the gas is dried with calcium chloride; then the sulphuretted hydrogen is taken up by a normal metallic salt, so selected or so manipulated as not to give up water or acid vapour to the desiccated gas, for which purpose crystallised blue vitriol answers best. The carbonic acid is next absorbed by sodic hydrate; and, lastly, the oxygen is separated by the application of alkalised pyrogallol or other suitable agent, arranged so as not to lose any water. The solid salts are broken for use into pieces about the size of a pea. Finally, the measurement (roughly) of the gas is made by a gas meter, the temperature being observed; if with a dry meter, directly; if with a wet meter, after saturation with moisture at the temperature of melting ice. In the latter event, the final quantity of moisture in the gas is determined by desiccation with calcium chloride.

The whole process is completed and the separation rendered as

sharp as may be by distillation in a current of the same gas that has previously been formed from the ingredients separated. After final weighings, the correct initial volume of the original mixture of gas and spray is calculated by means of formulæ derived from the crude meter indications and the final weighings, in which the original volumes of the several ingredients in their gaseous conditions are calculated in terms of their densities respectively, and added to the observed volume of the residual gas.

To illustrate the nature of the work done by means of the 'Analytical Train,' Mr. Wurtz gives the results of an analysis of gas made at the works of the Harlem Gas Light Company, New York, on a new principle, according to which the crude coal gas is forced through the liquid products of the retorts, constituting a species of straining of the gas through a liquid medium. The coal from which the gas was made was highly sulphurous, but rich, from West Virginia, known as the Murphy Run Coal.

RESULTS of ANALYSIS of GAS by MEANS of MR. WURTZ'S ANALYTICAL TRAIN.

Impurities.	Grains per 100 Cubic Feet.			
	Crude Gas from Hydraulic Main.	Condensed Gas from Inlet to Purifiers.	Difference, taken out by Scrubbers.	
	Grains.	Grains.	Grains.	Per cent.
1. Water	3,515·2	2,674·5	840·7	23·92
2. Tar	575·0	44·0	471·0	91·46
3. Smoke, soot, dust, &c.	265·9	55·7	210·2	79·05
4. Naphthaline (condensable)	123·5	25·0	98·5	79·77
5. Ammonia	339·4	237·0	102·4	30·18
6. Sulphuretted hydrogen	1,234·9	1,105·1	129·8	10·51
7. Carbonic acid	1,698·0	1,522·1	176·0	10·36
(By Volume.)	Cubic Feet per 100 Cubic Feet.			
	Cubic Ft.	Cubic Ft.	Cubic Ft.	Per cent.
Sulphuretted hydrogen	1·93	1·73	0·20	10·88
Carbonic acid	2·07	1·86	0·22	10·62
Average temperatures, Fahr.	107°·5	94°·6	..	..

The Paper contains a minutely-detailed description of the analytical trains designed by the Author, accompanied by several illustrations, various precautions for avoiding error and insuring accuracy of observation being given. The flask into which suspended matter is collected is one of great capacity; thence the gas traverses a series of U tubes of three sizes, of which the medium size, and that most commonly used, is 8 inches high, with a calibre of 0·9 inch, and a distance of 2 inches between the limbs. The usual rate of flow which is advisable is about 1 cubic foot per hour.

D. K. C.

Critical Examination of the Value of Naphthaline and Petroleum as Substitutes for Cannel Coal. By Prof. A. Wagner.

(Bayerisches Industrie und Gewerbeblatt, No. 1, 1875, pp. 1–5.)

With the object of improving some of the processes for increasing the illuminating power of poor gas, by adding materials containing naphthaline, the Author made a series of experiments. The mixture of naphthaline vapour with the gas, or the conversion of naphthaline into permanent gases of high illuminating power, by great heat, would give the desired result. But the Author shows that hydrogen, saturated with naphthaline vapour, deposited the latter almost completely at about 93° Fahr., the gas then burning with a feeble blue flame. As coal gas, even in summer, is cooled in the mains far below this temperature, naphthaline would fail to increase the illuminating power. It was also found that, when naphthaline and petroleum vapours were passed through incandescent tubes filled with pumice, the yield of gas was smaller than with petroleum alone, the naphthaline escaping decomposition. Hydrogen and naphthaline vapour were passed through white-hot pumice: the gas burnt with the pure blue flame of hydrogen. From these observations, the Author concludes naphthaline to be useless for the preparation of illuminating gas. As regards the distillation of coal or peat saturated with petroleum, or caustic or hydrated lime moistened with petroleum, it is shown experimentally, that the petroleum vapour, heated by itself, gives better results, and that pure petroleum gives a larger yield of permanent gas than the residues from the petroleum distillation.

One of the experiments was with petroleum having a specific gravity of 0·789, containing no constituents of which the boiling point was below 302° Fahr. About 80 grammes were distilled in a retort, the vapours were passed through a porcelain tube filled with pumice and heated to redness, the gaseous products were cooled by snow, and the permanent gases measured. The experiment lasted an hour and a half, by which time the boiling point had risen to 550° Fahr.; about $\frac{1}{3}$ of the petroleum was converted into permanent gas, $\frac{1}{3}$ was condensed, and $\frac{1}{3}$ remained in the retort. The gas obtained burnt with a smoky flame from ordinary gas-burners, but when mixed with a poor gas, it gave in suitable burners a good flame.

The following numbers permit some comparison between petroleum, Boghead coal and Saarbrück coal.

1 cwt. of	petroleum	yields	1,316	cubic feet of gas.
„	Boghead coal	„	641	„ „
„	Saarbrück „	„	455	„ „

The illuminating power of 1 cubic foot of gas from

Petroleum	3·14 oz. stearin.
Boghead coal	2·45 „ „
Saarbrück coal.	0·70 „ „

For an illuminating power of 300 lbs. of stearin, the gas obtained from 1 cwt. of petroleum, from 2·6 cwt. of Boghead coal, or from 12·5 cwt. of Saarbrück coal, would be required. The cost of 1 cwt. of petroleum in Europe is much greater than that of 2·6 cwt. of Boghead coal, and although 12½ cwt. of Saarbrück coal would cost more in many parts of Germany than 1 cwt. of petroleum, 8 cwt. of coke produced in the manufacture would cover half the outlay. The numbers for petroleum were obtained from experiments on a rather small scale, but supposing them to be verified by the experience of a larger trial, petroleum would be in Germany a dearer material than Boghead or Saarbrück coal.

W. H. D.

Notes on the Deposits of Fossil-Bitumen near Zaho, in Kurdistan, Asia Minor. By L. Mongel.

(Annales des Mines, part 1, 1875, pp. 85–91, 1 pl.)

This Paper contains a description of an immense deposit of a highly bituminous, rather bright black substance, with conchoidal fracture, found near Zaho, at a short distance from the river Tigris, about 440 miles above Bagdad, and between 700 and 800 miles from the Persian Gulf.

The width above ground of this deposit is about 145 yards; and the outcrop on the hillside indicates that it extends for upwards of 4,300 yards, with a minimum thickness of 55 yards, sometimes divided into layers by exceedingly thin veins of clay. The Author estimates the whole to contain 33,800,000 cubic yards of bitumen.

The exposed portion of the deposit being considerably above the bottom of the valley, several horizontal galleries have been driven into it, and in the course of the first twenty-two days the Author extracted 485 tons of bitumen. Owing to the absence of good roads, the present cost of conveyance on mules to the river Tigris at Rihamieh is between 7*s*. and 8*s*. per ton, and from thence to Bagdad the bitumen has to be carried in inflated skins on rafts of wood, at an expense of 33*s*. per ton. The total cost of the bitumen delivered at Bagdad is now £2 4*s*. 6*d*. per ton, which it is estimated might be reduced to £1 14*s*., so that if used instead of English coal, of which 10,000 tons, costing £4 10*s*. per ton, are annually consumed, there would be a saving of £28,000 per annum.

This bitumen has been employed experimentally with complete success for heating the engine boilers of the "Mossoul" steamer, of 80 HP., the quantity consumed per hour being as nearly as possible the same as of English coal. It was used also for heating a 12-HP. Cornish engine, and was found to have in this case a heating power slightly superior to coal, although it occasioned more smoke, in consequence of the grates not being well adapted for its combustion. Lastly, it was successfully applied to the

manufacture of gas; the coke which remained in the retort was of good quality, and the tar very abundant.

Several other outcrops of similar bitumen have been found nearer Bagdad, at Serranieh, and near Erbilla, and the Author also met with liquid petroleum exuding from the ground at many points upon the road from Rihamieh to Bagdad, for which, he thinks, it would be worth while to sink wells, fuel in those parts being rare and expensive.

O. C. D. R.

Sulphur Mines of Sicily. By Ch. Ledoux.

(Annales des Mines, part 1, 1875, pp. 1–84, 2 pl.)

Italy has hitherto enjoyed an almost exclusive monopoly in the supply of sulphur (brimstone) throughout the world; the mines in Spain, France, Greece, on the shores of the Red Sea, and elsewhere, being of secondary importance. There are a few besides in Tuscany and in the Romagna, but by far the largest number are in Sicily, where the annual production amounts to very nearly 200,000 tons. For the sake of economy, sulphuric acid is now commonly made from iron or copper pyrites; but these ores contain so much arsenic as to render the acid injurious in some industries, and if brimstone could be brought into the market somewhat below its present price, it would be preferred to pyrites, and its consumption would be much increased.

In the year 1871 the Author visited the mines of Lercara, Casteltermini, Racalmuto Caltanisetta, and Grotta Calda, but he has largely availed himself of information published in 1870 and 1871 by M. Mottura, who, by order of the Italian Government, made the geological map of the mining districts of Sicily, and likewise in 1873 by M. Parodi, both engineers of the Royal Italian Corps of Mines.

The production of sulphur in 1870 was—

	Metrical Tons.	Estimated Value when shipped.	Estimated Cost at the Mines.
In the district of Caltanisetta . .	70,429	£341,057	£136,233
" " Girgenti . . .	83,360	397,183	133,214
" " Catania . . .	19,180	96,113	33,603
" " Palermo . . .	7,358	36,787	11,831
Total . . .	180,327	871,140	314,881

About one-half of this sulphur was shipped at the port of Girgenti, and the rest from the ports of Licata, Catania, Torrenova, Messina, and Palermo.

The roads in Sicily are generally very bad, and a great part of the carriage of sulphur has to be performed on mule-back. From the district of Caltanisetta, however, about one-half is

conveyed in carts, and in the provinces of Palermo and Catania the miners are able partially to avail themselves of the two portions of the central railway now in operation; but the railway tariff is exorbitant, and the average cost of transport from the mines to the seaports amounts to about £1 per ton of sulphur.

The mines belong to the owners of the surface soil, and are usually leased for short periods, averaging nine years, to the miners or mining companies at rates varying from 20 per cent. to 50 per cent., and averaging at least 25 per cent. of their gross annual product. This is equal to a royalty at the rate of 16*s.* 5*d.* per ton of the produce. Such an arrangement is very prejudicial, as it becomes an inducement to the miners to work only the richest veins, and large quantities of ore less rich in sulphur are left in the mines and wasted. There is also so much dishonesty in the conduct of all the operations, that M. Parodi asserts that the management of this industry is, in the majority of cases, nothing less than an organised brigandage.

The geological formations in which the sulphur is found, commencing at the surface, usually occur in the following order:—

1. Marly limestone (called Trubi).
2. Saccharoïd gypsum containing fossil fresh-water fish.
3. Argillaceous limestone and marl, mixed with beds of sulphur and gypsum.
4. Compact limestone, sometimes silicious.
5. Tripoli, containing numerous fresh-water shells and fossils of fish and insects.

Below these formations deposits of rock salt are met with, and also bituminous deposits which often contain petroleum.

The gypsum (hydrated sulphate of lime) appears to have a close connection with the sulphur beds, and to owe its origin to similar causes, which must have formed both simultaneously.

The sulphur ore is disseminated through the mass of calcareous matter, sometimes in irregular veins, or pockets, and sometimes in small beds parallel to the stratified limestone, clay, or gypsum. The beds of ore vary from 6 feet to 27 feet in thickness, the usual average being about 13 feet, as at Caltanisetta. At Grotta Calda there are three beds, separated by from 3 feet to 5 feet of marl.

At the great mine of Sommatino there are six beds of sulphur ore varying from 6 feet to 26 feet in thickness, separated by unproductive layers, each about 3 feet thick.

At La Croce (Lercara) the sulphur beds attain a thickness of 114 feet. There is great irregularity both in the inclination and in the direction of the beds. The outcrops rarely contain any sulphur.

The average richness of the ore in sulphur is:

	Per cent.
At Madore (Lercara).	20
At Grotta Calda	25 to 27
At Sommatino	22
At Cimicia (Racalmuto)	21

In other mines it falls as low as 11 and 12 per cent.

The mines are worked in a most primitive way; vertical shafts, horizontal galleries, and the use of timber, are unknown. When the inclination of the beds does not exceed 45°, it is customary to commence by working downwards in the bed, and to cut steps in it so as to allow the ore to be brought up on the backs of boys and young men of from eight to eighteen years of age, who carry, according to their strength, a weight of ore varying from 40 lbs. to 80 lbs. At all the three hundred and fifty mines in Sicily, with the exception of four, the ore is brought in this way to the surface —the boys being employed and paid by the pickmen. The consequence of this is that the carriage of the ore to the surface is the most costly item in the whole of the mining expenses.

The average daily work done by a pickman is rather less than 1 cubic yard of ore, which measures in the pile 1·5 cubic yard, and weighs 1 ton 8 cwt. His wages average 2*s.* per diem; but the price paid to the miners always includes the total cost of extraction, piling the ore, oil, tools, powder (when used), &c.

When the mine is not more than from 131 feet to 164 feet in depth, and not much water is met with, if the annual production is at the rate of from 5,200 to 6,500 cubic yards, the average cost of extracting the ore, according to M. Parodi, is as follows:—

	s.	*d.*	
Mining	1	4·3	
Carriage to surface	1	7·2	
Tools and oil	0	3·8	
Piling the ore	0	1·9	
Maintenance of the works	0	5·7	
Pumping water	0	1·9	
Superintendence	0	2·7	
Total	4	3·5	per ton of ore.

To these figures must be added:

	s.	*d.*
1. General management expenses and interest on working capital	0	5·5
2. Tax of about 3 lires per ton of sulphur	0	4·1
3. Amortisation of capital	0	1·3
	0	10·9

which brings up the total mining expenses to an average of 5*s.* 2·4*d.* per ton of ore.

Fusion of Ores.

As sulphur will melt at the low temperature of 239° Fahr., it would appear, at first sight, to be an easy matter to separate the metalloïd from the matrix. But singular difficulties are found to interfere with this in practice. If the temperature is raised

above 320° Fahr. the sulphur becomes viscous, and it is not easy to keep the temperature between the limits of 239° and 320° Fahr. Then, also, fuel is expensive in Sicily, and a barbarous system of burning the ore in kilns or calcaroni, has, in consequence, become generalised throughout the country. This system consists in piling the ore on a sloping floor, surrounded by a low wall, and setting fire to the upper portion of it. As the fire gradually descends the lower layers are heated, and the liquid sulphur runs off and collects at the bottom. The calcaroni are built of all dimensions, varying in capacity from 32, 65, 162, 585, to even 1,560 cubic yards. They require to be carefully charged, as negligence in this respect will occasion a loss of 10 per cent., or more, of sulphur. The largest lumps of ore are placed at the bottom and in the centre, the smallest at the top and round the sides. Upright flues are built at intervals in the ore to facilitate the combustion. At the lowest point of the sloping floor a narrow and thin partition, called the *morte*, is so arranged that the liquid sulphur all converges at this point, and when a sufficient quantity has collected it is drawn off into moulds through small holes tapped in the *morte*. From three to four weeks are usually required to melt sufficient sulphur to commence drawing off, and it continues to melt and to be daily tapped during a further two or three weeks. The largest calcaroni require three months for the complete operation.

There is, of course, a great deal of sulphur burned and wasted by this process. The loss often amounts to 50 per cent., and can rarely be estimated at less than 35 per cent. A great deal of experience is requisite on the part of the men who attend to the fusion, and they form a special class called *arditori*. Ores containing less than 15 per cent. of sulphur cannot be treated in calcaroni, as the loss incurred with such ores is so considerable that their fusion is altogether unprofitable. A gypsum matrix gives very unfavourable results, because much heat is wasted in vaporising the hygrometric water, and some sulphuret of lime is formed, which darkens the colour of the sulphur.

So much sulphurous acid escapes from the calcaroni that, being injurious to the surrounding population and vegetation, they are required by law to be placed at a minimum distance of 220 yards from dwelling-houses, and of 110 yards from cultivated lands, otherwise they may only be used between the 1st of August and the 31st of December.

The sulphur thus obtained is discoloured by the action of the fire, and requires to be refined by distillation after it is brought to France or to England.

The average net production of sulphur from the ore when fused in calcaroni is:

	s.	d.	
At Madore, 12 per cent., and the cost of fusion .	7	0·5	per ton of sulphur.
At Racalmuto, 14 per cent., " " .	4	4·8	" "
At Grotta Calda, 17 per cent., " " .	3	10·0	" "

M. Parodi estimates the average cost of 1 metrical ton of sulphur fused in a calcarone to be:

	s.	d.
By 7 tons of ore, at 5s. 2·6d. per ton . . .	36	6·2
By fusion of ditto	4	2·8
	40	9·0
Add royalty to the owner of the soil . . .	12	0·0
Cost of 1 metrical ton of sulphur . .	52	9·0

But the Author considers this price too low, and is of opinion that the average royalty cannot be taken at less than 16s. 4·8d. per ton, because the value of the sulphur at the mines is 65s. 6d. per ton, and the average royalty is one-fourth of the gross product in sulphur.

Fusion of the sulphur by means of steam under pressure has been introduced at some of the mines, as at Lercara, Sommatino, La Croce, Floristella, and at Latera, in the Romagna. It has not everywhere answered, and at Montedoro where the matrix is argillaceous, after adopting the process in 1871, it had to be abandoned; but, notwithstanding the contrary opinion of M. Parodi, the Author expresses himself much in favour of it. The apparatus introduced by the Milanese Company, which owns the patent, consists of an upright cylindrical iron vessel holding about 3½ tons of ore, and pierced with small holes to admit the steam, over which is placed another air-tight iron cylinder of somewhat larger dimensions, between which and the first the steam is admitted. The steam is generated under a pressure of about 52 lbs. above the atmosphere, and has a temperature of 302° Fahr. It penetrates the ore throughout, and in about one hour forty-five minutes the sulphur is fused and run off into moulds. This apparatus can be charged every day seven times, and will melt about 24 tons of ore per diem. The consumption of coal in the boilers used at Lercara, for heating four such apparatus, is 2 tons 8 cwt., or at the rate of 12 cwt. per diem for each 24 tons of ore. Each apparatus costs £240 delivered at the mines, and the cost of the boilers, buildings, and installation comes to about as much more.

The cost of fusion by this process is estimated by the Author as follows:—

	Per Ton of Ore. s.	d.	Per Ton of Sulphur. s.	d.
Labour engineer and stokers	0	2·0	0	9·6
Labour charging and discharging the ore . .	0	9·6	4	0·0
Coals, at 47s. per ton	1	1·5	5	7·2
Water, at 3s. 7·8d. per cubic yard	0	8·1	3	4·3
Maintenance	0	3·3	1	4·3
Superintendence and management	0	2·2	0	10·5
Amortisation at ⅕th of £480 per annum per apparatus, &c.	0	4·2	1	9·1
Total	3	6·9	17	9·0

This does not include the sum charged by the patentees, who sometimes undertake the fusion by contract, at from 29 to 32 per cent. of the gross production of sulphur, and sometimes charge for the use of the apparatus at the rate of £180 per annum, which charges the Author considers excessive.

The cost of fusion by the steam process is thus seen to be much greater than when calcaroni are employed; but, on the other hand, there is a considerable saving in the quantity of ore required to produce each ton of sulphur. Thus ores containing respectively 26, 21½, and 16½ per cent. of sulphur will yield, by the steam process, 24, 20, and 15 per cent., and by the calcaroni, only 17, 14, and 10 per cent.

It follows that the quantities of ore required for the production of 1 metrical ton of sulphur are respectively:

	Tons.	Tons.	Tons.
When steam is used . . .	4,170,	5,000, and	6,670.
When calcaroni are used . .	5,880,	7,140, and	10,000.

And the total cost of the ore is:

	s. d.	s. d.	s. d.	
When steam is used . . .	21 10,	26 2, and	34 10	per ton of sulphur.
When calcaroni are used .	30 11,	37 5, and	52 4	„ „

Taking into consideration this saving in the cost and quantity of the ore, it appears that, notwithstanding the heavy payment to the patentees, an economy is effected by the use of steam in the fusion of the richer ores amounting to:

	s. d.	
When using ores containing 26 per cent.	1 0	per ton of ore.
„ „ 21·5 „	0 3·3	„ „

But when using ores containing only 16·5 per cent., the economy results in favour of the calcaroni at the rate of *5d.* per ton of ore.

This calculation is based on the supposition that the average cost of the ore is *5s.* *5·2d.* per ton, and the average value of sulphur at the mines *65s.* *10d.* per ton, the royalty to the patentees being *8·5d.* per ton of ore.

The sulphur is worth at the mines *65s.* *10d.* per ton when the average shipping price at the seaports is *96s.*, which is the value put upon it by M. Parodi, who gives the following analysis of this price:—

	s.	d.
Cost of sulphur at the mines, including royalty to the owner of the soil	52	10
Miners' profit	12	10
Carriage to the seacoast	19	10
Shipping charges	2	6
Export duty.	8	0
Shipping price of sulphur	96	0 per ton.

The present shipping price is higher than this.

The Author quotes M. Parodi to show that it would be possible when the railways in the island are completed, by reducing their

tariff from 2*d*., which is now charged, to 0·8*d*. per ton per mile, and by also remitting the export duty, to lower the shipping price of sulphur to 76*s*. per ton, which would allow of its being sold at Marseilles at from 88*s*. to 92*s*., and in England at from 100*s*. to 104*s*., in which case it might compete with pyrites at Marseilles; but, for reasons which he gives, he is not of opinion that such a reduction in the price is at all probable.

O. C. D. R.

On the Smelting Works of the Mechernich Mining Company at Mechernich, in Rhenish Prussia. By H. Jäger.

(Berg und Hüttenmännische Zeitung, April 16, 1875, 4 pp.)

These works were built in the year 1869 for the purpose of smelting the ores used in the Meinertzhagen mines, in the district known as the Bleiberg of Commern, which up to 1867 had been sold to the Stolberg works. The ores raised from the western part of the same district belonging to a French proprietary are also treated, and a further quantity of pure foreign ores are purchased. The quantities treated in the year 1874 were as follows:—

	Tons (Metrical).		Lead per cent.
From the Eastern district	17,492	with	60
„ Western „	3,018	„	56
Purchased ores	2,146	„	69
Old dressing waste	931	„	19

The local ores, which are obtained from a stratified sandstone containing small particles of galena scattered through it, are mixtures of galena with about 20 per cent. of quartzose sand, the proportion of silver being from 6 to 8 ounces per ton.[1] The old waste consists chiefly of carbonate of lead, with about 47 per cent. of sand. The purchased ores contain about 20 ounces of silver to the ton of lead. The ores are slowly calcined in a double-bed calciner, until the whole of the sulphur is removed, and the oxides formed combine with the silica to form a glassy slag fusible at a red heat. The furnace contains from 50 to 55 tons. The charges are so worked, that from 8 to 10 tons are drawn in twenty-four hours; from five to six days being required for the complete calcination and fusion of the ore. There are ten calcining furnaces, each served by four men. The consumption of coal is about 15 per cent. of the weight of the ore; the sulphur in the roasted ore is reduced to 0·7 per cent.

The calcined ore is smelted with calcareous and ferruginous fluxes in blast furnaces for work-lead with a small quantity of

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[1] The mode of occurrence, methods of working, and older processes of smelting the ores from this remarkable deposit are described in Percy's "Metallurgy of Lead," p. 350.

regulus, in which the copper and metals of the ore other than lead and silver, are concentrated, being produced at the same time. The furnaces are cupolas, about 12 feet high and about 5 feet in diameter at the tuyeres, and 6 feet at the throat. Either three, four, or five tuyeres are used of 2½ inches diameter, blast being supplied by two Schiele's fans at a pressure of about 10 inches of water.

The furnaces are of common bricks, not too hard burnt; they resist corrosion better than the best fire-bricks. The hearth is made of clay and coke-dust 'brasque.' The average time of each blast is from three to four months. The composition of the ordinary smelting charge is as follows:—

	Cwt.
Calcined and slagged ore	90
Puddling furnace cinder	55
Flue deposits	10
Calcareous hæmatite	10
Limestone	40
Slags from former smelting	25
Coke	22

The materials, including the coke, are mixed up into heaps of about 12½ tons. The furnace is charged by shovels, and the surface levelled in the throat after charging. Four out of eight furnaces are kept at work, and produce, from 212½ tons of materials charged per day, from 40 to 50 tons of pig lead. The slags, which contain on an average from 0·3 to 0·5 per cent. of lead, are tested every day, and if found to contain more than 0·7 per cent., are returned to the furnaces. The amount of regulus obtained, on account of the perfect removal of the sulphur in the roasting furnaces, is small, not exceeding from 1½ to 2 per cent. of the weight of the lead.

The desilverizing of the furnace lead is effected by zinc. The lead is melted in pots containing 18 or 19 tons, and zinc is added in two portions—the first being 0·94 per cent. of the weight of the lead under treatment, and the second 0·13 per cent., or 1·07 per cent. in all. After each addition the contents of the pot are well stirred together and allowed to cool, when the zinc separates as a crust on the surface, which is skimmed off as long as any continues to form, and until the lead is cooled to the crystallizing point. The desilverized lead, which does not contain more than 3¼ dwt. of silver per ton, is refined by steam in a reverberatory furnace so arranged that the lead can be run into it directly from the desilverizing pots, of which there are two to each furnace. After removing the zinc and antimonial scum the softened lead is run into the market pot, whence it is cast into pigs. The arrangements for desilverizing and softening are adequate for treating 55 tons of lead per day. In January 1875, 1,150 tons of market lead were produced in twenty-one working days.

The dross and skimmings from the softening furnaces are smelted in a cupola furnace for slag lead. This on refining gives

rise to a more antimonial dross, which is smelted for hard lead when a sufficiency has accumulated.

The argentiferous zinc skimmings, after the separation of the excess of lead by liquation, are smelted in a blast furnace, with an addition of 30 per cent. of puddling furnace slags, 50 per cent. of slags from former smelting, 150 to 200 per cent. of lead furnace regulus, and 15 per cent. of coke. The products are rich lead, containing 2½ to 3 per cent. of silver; copper regulus, with from 10 to 12 per cent. of copper, 10 per cent. of lead, and 100 to 150 ounces of silver per ton; and slags with 0·2 to 0·3 per cent. of lead, and 2 to 3 ounces of silver per ton. The slags are returned to the ore-smelting furnaces. The regulus is passed through the blast furnace twice, with an addition of 50 per cent. by weight of products containing lead, but free from silver, for the purpose of removing the silver—the ultimate product being a concentrated copper regulus amounting to about one-twelfth of the original weight of the lead furnace regulus treated, and containing 25 to 30 per cent. of copper, 10 per cent. of lead, 2 to 3 per cent. of nickel, and from 60 to 120 ounces of silver per ton, which is sold to works smelting nickel and copper ores.

The rich argentiferous lead is refined in an English cupellation furnace with a movable test; the litharge, which contains about 120 ounces of silver per ton, is revived, and the lead desilverized. The cake of silver produced assays from 950 to 980 thousandths fine, and is remelted in a wind furnace in blacklead crucibles, with the addition of a small quantity of bone-ash, which absorbs the remaining litharge, and brings up the fineness to from 998 to 999 thousandths. The loss of silver in the treatment in the blast furnace, of the 'rich scum,' as the argentiferous zinc is called, is said to be inconsiderable; from the fact that the amount contained in the fumes collected from the condensing chambers attached to the blast furnace, in which the fusion takes place, is only 0·07 per cent. on the total quantity of silver produce.

The total amount of fume collected during the year 1874 in the condensing flues in connection with the different furnaces was 1,122 tons, containing 61 per cent. of lead, and about 1¾ ounce of silver per ton.

The total produce of the works during the year 1874 was—

Lead	12,400 tons.
Silver	101,324 ounces troy.
Copper regulus	39·2 tons.

The number of hands employed during slack times is from two hundred and fifty to two hundred and seventy.

The market lead from these works contains from 2¾ to 3¼ dwts. of silver, and from 6 to 8 dwts. of copper to the ton. The zinc is removed in the refining to within 2 to 3 dwts. per ton.

H. B.

On the Erection of Zinc-works, and the Metallurgy of Zinc.

By FRANCIS LAUR.

(Bulletin de la Société de l'Industrie Minérale, No. 3, 1874, pp. 395–445.)

The importance of carefully selecting a site for zinc-works is obvious, when it is stated that the production of 1 ton of this metal requires nearly 10 tons of material, viz., 6 tons of coal, 3 tons of ore, and 7 cwt. of fire-bricks and clay.

Since an establishment capable of yielding 10,000 tons of zinc annually will require from 90,000 to 100,000 tons of material, the smallest saving in the cost of transport of ores and fuel may materially influence the financial aspect of an undertaking. The establishment of zinc-works also requires a considerable amount of capital, on account of the numerous accessories necessary for the production of various forms of merchantable zinc.

The Author states that, having been called upon to study this problem, on the occasion of establishing large zinc-works in the South of France, he had become impressed with the importance and complication of the preliminary calculations which should be made before fixing upon a site for such works. The present Paper embodies the results of his observations.

The zinc trade is now passing through a crisis, the result of three causes, viz.: the labour difficulty, absence of improvement in the processes employed, and the unfavourable position of many of the established works.

With respect to the metallurgy of zinc, no progress has been made since the year 1830. The treatment of zinc ores consists in heating a mixture of impure oxide of zinc and carbon in close vessels, to which are adapted appliances for the condensation of the resulting metallic vapours. Two things only admit of being varied in this arrangement; the apparatus containing the vessels to be heated, and the retorts themselves in which the reduction of the zinc is effected. Almost every possible modification of these elements has, at one time or another, been tried. There have been furnaces inclosing a large number of retorts, and retorts holding a large quantity of ore; small furnaces with large muffles of the old Silesian type, and small furnaces containing numerous small retorts of the old Belgian form; there are also capacious furnaces with large distilling vessels, as at Angleur, and others, as at Flône, with a lower row of large muffles and an upper one of smaller cylinders; large furnaces with two or three rows of small muffles have likewise been tried. These experiments have, however, indicated that the dimensions of the vessels and furnaces cannot be safely changed except within certain limits, and in the best-managed establishment something like a mean has been ultimately arrived at.

Notwithstanding the difficulty of such generalisations, a review of the experiments on the relative size of the furnaces and of the

inclosed distillatory apparatus appears to lead to the following practical rules:—

1st. It is not prudent to construct furnaces of which the internal capacity materially exceeds 32·5 cubic yards.

2nd. The thickness of the charge to be reduced in the vessels, crucibles, or muffles, should not exceed 7 inches; and the vessels should never be more than 19·7 inches in height and 4·92 feet in length.

3rd. A capacity of 22 gallons is regarded as the maximum which can be advantageously given to a vessel in which distillation is effected.

4th. The total interior available volume of the whole of the distillatory vessels placed in the heating chamber should be about one-third of the volume of the interior of the chamber itself. Experience shows that nearly two-thirds of the interior capacity of a furnace is required for the supports, and for the free circulation of flame, and heated gases.

The fireplace is entirely independent of these data, as the problem varies with each locality, with the nature of the fuel, and with the type of furnace. In all cases, however, a bright-red heat should be attained, and this temperature should equally pervade every part of the furnace.

The normal loss of zinc may be taken at 20 per cent. of the metal produced.

The following is the total annual production of zinc in Europe:—

	Tons.		Tons.		Tons.
1846 . .	40,000	1857 . .	79,000	1866 . .	110,000
1850 . .	50,000	1858 . .	90,000	1870 . .	130,000
1853 . .	62,000	1860 . .	98,000	1873 . .	129,000
1856 . .	71,000	1862 . .	100,000		

M. Laur's Paper is accompanied by drawings, and, besides minutely describing the different processes for the treatment of zinc ores, furnishes cost of production, together with estimates for erection of plant; it may therefore, to a great extent, be regarded as a monograph on the present state of the metallurgy of zinc.

P. B.

On Spiegeleisen. By MM. L. Troost and P. Hautefeuille.

(Comptes-rendus de l'Académie des Sciences, April 5, 1875, pp. 909–911.)

Ordinary cast iron, in cooling, throws out sparks, whereas spiegeleisen has a constant sheet of flame playing over its surface, which has the appearance of hydrogen, certainly not of carbonic oxide.

The spiegeleisen also contains, after solidification, a much larger quantity of hydrogen than ordinary cast iron, as is shown by the

following results, obtained from heating 500 grammes of each to 1472° Fahr. :—

	Ordinary Cast Iron.		Spiegeleisen.
	Grammes.		Grammes.
Carbonic acid	0·6	..	0·0
Carbonic oxide	2·8	..	0·0
Hydrogen	12·3	..	27·0
Azote	1·0	..	2·5
	16·7		29·5

From these results, the Authors conclude that the presence of spiegeleisen increases to a great extent the solubility of hydrogen in the metal, and diminishes that of carbonic oxide.

E. B.

On the Limit of the Carburation of Iron. By M. BOUSSINGAULT.

(Comptes-rendus de l'Académie des Sciences, April 5, 1875, pp. 850–858.)

It is impossible to derive a limit of carburation from the variable proportions of carbon entering into commercial iron, combined as it is with manganese, sulphur, &c. To discover whether iron and carbon form a fixed compound, no dependence can be had except on experiments made with compounds containing only iron and carbon, both in a state of purity. Dr. Percy gives 4·4 per cent. as the maximum of carbon able to combine with iron. Karsten gave 5·1 per cent., stating that with this proportion a fixed compound was formed, represented by Fe_4C. The Author could trace no decided difference in combined carbon between white and grey cast iron. The maximum he asserts to be 4·06 per cent., and that any surplus of carbon is in the form of graphite. If an iron containing this quantity solidifies quickly, it is homogeneous, and retains in the solid state the whole of the carbon, whereas, if cooled slowly, it is not homogeneous, there being combined and free carbon, and probably pure iron. Experiments were made at the works of Mr. Holtzer, at Unieux, with Swedish iron containing 0·9961 of metal, of which 22 lbs. broken in pieces, with the intervals filled with wood charcoal, were melted in a crucible in a Siemens furnace. The metal was run on a cast-iron plate; the lower portion of the mass was white, the upper being grey. The following was the result of the analysis:—

	Iron.		Combined Carbon.		Graphite.		Total Carbon.
In the mass	95·90	..	2·10	..	2·00	..	4·10
In the white zone	95·99	..	3·585	..	0·425	..	4·01
In the grey zone	95·22	..	2·67	..	2·11	..	4·78

The white zone, in which the proportion of graphite was only 0·004, has nearly the theoretical composition Fe_5C, in which

Iron	=	95·90
Carbon	=	4·10
		100·00

The whole of the carbon was, undoubtedly, in combination in the liquid state, and the graphite was formed on the metal cooling. The Author, finally, considers there is nothing more curious than the changes in the nature of iron combined with a maximum of carbon produced by the influence of temperature: grey iron transformed into white, by the union of free carbon and free iron; and, reciprocally, white iron changed into grey, by carbon and iron being set at liberty.

E. B.

On the Analogy between the Nature of Steel and its Magnetic Properties. By MM. TRÈVE and DURASSIER.

(Comptes-rendus de l'Académie des Sciences, March 29, 1875, pp. 799–802.)

The aim of the Authors' experiments was to find the relative quantity of magnetism which a piece of steel could retain, as the quantity of carbon and its degree of temper were varied. The experiments were made on fifteen bars, containing five different amounts of carbon, and tempered to three different degrees. The bars were first raised to 1412°·6, and 1472° Fahr., as measured by Mr. C. W. Siemens's electrical pyrometer, and afterwards tempered at 50° Fahr. and 212° Fahr. in water, and at 50° in oil. Steel tempered in water at 50° Fahr. retained most magnetism, that at 212° stood next, whilst that tempered in oil contained least. With respect to the effect of carbon, the Authors conclude: "The similarity found between the magnetic curves and those of elasticity, in all these steels containing various quantities of carbon, proves that, if carbon gives elasticity to steel, it also gives it the power of retaining magnetism."

E. B.

On Involute Teeth for Elliptical Cog-wheels.
By PROFESSOR DR. KIRSCH.[1]

(Civilingenieur, vol. xxi., pp. 223–230.)

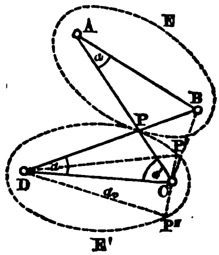
Let a straight line, A B (Fig. 1), revolve round another line, C D, of equal length ($2c$), in such a way that it describes a circle round the centre, C, with a radius A C = $2a$, and B describes a circle round D with the same radius, then the triangle A B C will be in any position coincident with D C B, and consequently

$$AP = PD,\ BP = PC$$
$$AP + BP = DP + CP = 2a.$$

The latter equation shows that the point P of intersection between the two rays A C and B D describes round the fixed line C D, as well as round the revolving line A B, coincident ellipses, whose foci are respectively C, D and A, B.

In this process nothing is altered if, instead of rolling one ellipse upon the other, both are revolved round the fixed points A and C.

FIG. 1.



Two wheels so placed will be able to work in gear together, and a uniform speed in the driving wheel will produce a varying speed in the driven wheel. Let E' be the driving wheel, and let it turn half a revolution, so that the point P travels from P' to P'', then the driven wheel E will describe an angle of $2\,\alpha_0$ degrees, whilst during the time E' makes the other half revolution E will describe an angle of $360 - 2\,\alpha_0$ degrees.

The ratio of irregularity is therefore

$$n = \frac{360 - 2\,\alpha_0}{2\,\alpha_0} \text{ and } \alpha_0 = \frac{180}{n+1}.$$

In Fig. 1

$$P^1 D^2 = (2\,a - P^1 C)^2 = P^1 C^2 - C D^2$$

$$P^1 C = \frac{a^2 - c^2}{a}; \quad \tan \alpha_0 = \frac{a^2 - c^2}{2\,a\,c} = \tan \frac{180}{n+1}$$

$$c = a\,\frac{1 - \sin \frac{180}{n+1}}{\cos \frac{180}{n+1}}.$$

This formula serves to calculate for a certain size of elliptical wheels (given by the transverse $2\,a$), and a certain required irregularity, n, the necessary focal distance $2\,c$.

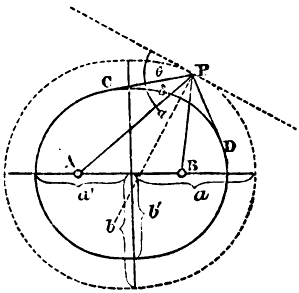
If a point P (Fig. 2) travels round an ellipse in such a manner that a cord passed round the ellipse and this point is kept tight, the latter describes an ellipse which has the same foci as the original one. As the velocity in the direction C P is equal to the velocity in the direction P D, the angles which those two tangents include with the outer curve are equal:

$$\vartheta = 90 - \alpha - \delta.$$

This angle ϑ gets extreme values where the point P passes the transverse and conjugate axes, viz.:

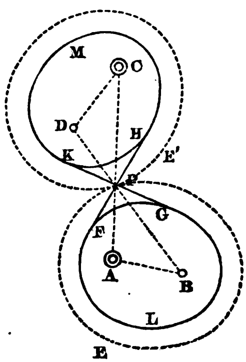
$$\cos\vartheta = \frac{a^1}{a} \qquad\qquad \cos\vartheta = \frac{b^1}{b}.$$

FIG. 2.



Let now E and E′ (Fig. 3) be two elliptical wheels, placed in such a position that they are able to work in gear together and wind a rope, K M H F L G K, round two smaller coincident ellipses with the same foci as the first, then it will easily be seen that the angles A P F, B P G, C P H, D P K are equal, and therefore the point P lies always in the centre line A C. As, according to Fig. 2, the length of the rope is the same for every position, it will

FIG. 3.



be possible to drive the smaller ellipses by means of a crossed strap, in exactly the same manner as the larger ellipses would work together in gearing. Any point chosen in the tangents F H and G K describes involute curves with regard to the inner ellipses,

and those curves can therefore be used to shape after them the teeth of the wheels E and E′.

The inclination of the flanks of teeth towards the pitch lines E and E′ depends upon the size of the inner ellipses, and it is easy to determine out of the two last equations for cos ϑ how those ellipses have to be chosen, in order that the angle ϑ does not exceed a certain limit.

G. K.

On the Transmission and Distribution of Motive Power by Wire Ropes. By M. ARTHUR ACHARD.

(Annales des Mines, part 4, 1874, pp. 131–175.)

The transmission of power to great distances by wire ropes is only an extension of the ordinary transmission by belt and pulley. The system consists of—(1) Two shafts, assumed to be parallel. (2) Two pulleys, assumed to be in the same plane. (3) An endless belt or rope, passing round them. This may at any instant be conceived as divided into four parts—(1) The part coiled upon the driving pulley. (2) The tight or leading span. (3) The part coiled upon the following pulley. (4) The loose or trailing span.

To commence with the simplest theoretical case: The rope is supposed to be perfectly light and flexible, and the shafts to be perfectly smooth. Let R be the radius of the driving pulley, and let a power, P, act upon it tangentially to a circle of radius r. Let R′, r' be similar quantities for the following pulley, Q, the resistance also tangential. Let T be the tension of the leading, t of the trailing span.

Then, supposing the motion to be uniform, the conditions of equilibrium of the two pulleys give the following:—

$$T - t = P\frac{r}{R} = Q\frac{r'}{R'}.$$

Another equation is required to determine T and t. This is given by the supposition that the tension will be as small as possible consistent with the ropes not sliding upon the pulleys. Let α and β be the arcs of the driving and following pulleys embraced by the rope, f the co-efficient of friction between the rope and the pulley; then, by a well-known principle, the rope will be on the point of slipping over the driving pulley when $\frac{T}{t} = \epsilon^{f\alpha}$.

Hence the equation required to determine the tension is $\frac{T}{t} = \kappa$, where κ is the smaller of the two quantities $\epsilon^{f\alpha}$ and $\epsilon^{f\beta}$. In practice the tension would have to be greater than this, and should therefore be written $\frac{T}{t} = \mu\kappa$, where μ is some quantity less than l.

The resistances of the system must now be introduced, viz., the friction of the shafts on their bearings, and the stiffness of the rope. Let f be the co-efficient of friction for the bearings, then the total friction on either shaft is f_1 F, where F is the resultant of all the forces acting on the shaft at right angles to its length, and the moment of this friction about the axis is $f_1 \mathrm{F} \rho$, ρ being the radius of the shaft.

The effect of the stiffness is only apparent where the rope rolls on to the pulley. It there causes it to bend gradually instead of abruptly from the straight line to the curve of the pulley, and therefore to stand out a little from the latter at the point of junction. This lengthens the arm at which the tension acts by a quantity which M. Achard assumes to be $= s\,\Delta^2$, Δ being the diameter of the rope, and s a co-efficient depending on the material. The equations then become

$$\mathrm{P}r + t\mathrm{R} - \mathrm{T}\,(\mathrm{R} + s\,\Delta^2) - f_1\,\rho\,\mathrm{F} = 0;$$
$$\mathrm{T}r' - t\,(\mathrm{R}' + s\,\Delta^2) - \mathrm{Q}r' - f_1\,\rho'\,\mathrm{F}' = 0;$$

and as before
$$\frac{\mathrm{T}}{t} = \mu\,\kappa.$$

Since F is a function of P, T, t and the weight of the driving pulley and shaft, while F′ is a function of Q, T, t and the weight of the following pulley and shaft, it follows that there are three equations to determine the three unknown quantities, T, t, and P or Q, according as it is the power or the resistance which is to be found.

It must be observed that hitherto the two spans of the rope have been supposed straight, which is approximately true in the case of leather belts, but not of wire ropes. The section of the rope must be found by dividing T, the greater tension, by the working strain of the material. But (omitting the resistances)

$$\mathrm{T} = \frac{\mu\,\kappa}{\mu\,\kappa - 1} \times \mathrm{P}\,\frac{r}{\mathrm{R}}.$$

Now $\frac{r}{\mathrm{R}} = \frac{v^1}{v}$, where v is the velocity of the rope, v^1 that of P's point of application. Moreover, if N be the effective HP. of the prime mover, $\mathrm{P} = \frac{550\,\mathrm{N}}{v^1}$; hence substituting

$$\mathrm{T} = \frac{\mu\,\kappa}{\mu\,\kappa - 1} \times \frac{550\,\mathrm{N}}{v},$$

or the tension of the rope varies inversely as its velocity. Thus by increasing the velocity the power transmitted by a rope or belt of given strength can be increased. There is, of course, a practical limit to the velocity, and therefore to the power; which last can be calculated from the above equation by taking v = the maximum velocity. It thus appears that leather belts, from their small tenacity, are not well adapted for transmitting

great power. M. Achard considers that about 100 HP. is the maximum that a belt can convey. For this reason, and on account of their greater durability, wire ropes are much to be preferred where the distance and power are considerable.

This case is now considered. Owing to the weight of the rope it cannot be taken as a straight line. It will, in fact, be a catenary; but to simplify calculation, it is assumed to be a parabola, which is the form it would assume if the weight were evenly distributed along the horizontal line joining the extremities, and not along the rope itself. As in practice the 'sag' of the rope is always small, the difference between the two curves is inappreciable. The line joining the extremities is taken as the axis of x, its middle point as the origin, and the axis of y is measured downwards. Let l be the length of this line, h the total 'sag' at the lowest point, S_o the tension at that point, S the tension at any other point $x\,y$, p the weight per unit of length. Then

$$S = \sqrt{S_o^2 + p^2 x^2}, \quad h - y = \frac{p\,x^2}{2\,S_o}.$$

Since $y = o$ when $x = \frac{l}{2}$, then $h = \frac{p\,l^2}{8\,S_o}$; hence, substituting

$$S = \frac{p\,l^2}{8\,h}\sqrt{1 + \frac{64\,h^2 x^2}{l^2}},$$

S will be greatest at the extremities of the span, *i.e.*, when $x = \frac{l}{2}$: at these points

$$S_1 = \frac{p\,l}{8}\sqrt{\frac{1}{\left(\frac{h}{l}\right)^2} + 16.}$$

If a be the length of the span (considered as a parabola) then approximately $a = l + \frac{8}{3}\frac{h^2}{l}$; hence, substituting

$$S_1 = \frac{p\,l}{4}\sqrt{4 + \frac{2\,l}{3\,(a - l)}},$$

which gives a relation between the tension at the extremities and the length of the span.

From these equations it is possible either to determine the length of span (or the sag at the centre) for a given tension, or *vice versâ*. The tension will of course be due to the tractive power at the circumference of the driving pulley, and the first effect of applying a given power will be to tighten the leading span until the right amount of tension is produced to balance the traction and render the motion uniform.

Assuming a maximum working tension for the ropes, the minimum sag for a given span can easily be calculated. This is

much greater proportionally for large spans than for small ones, varying nearly as the square of the length.

By substituting for S_1 the tensions T and t of the leading and trailing spans respectively, as previously determined from the equilibrium of the pulleys, the sag of the leading and trailing spans can be found. If the difference between these approaches to the length of a diameter of the pulley the trailing span must be the lower, otherwise there would be danger of the two coming together; should this not be the case the trailing span may be the upper, which is often more convenient.

Let a_1 a_2 be the lengths of the leading and trailing spans respectively, then $\frac{a_1 + a_2}{2}$ is the common length when the system is at rest. By substituting the value found for h in the equation $a = l + \frac{8}{3} \frac{h^2}{l}$ then

$$a = l \frac{S_1^2 - \frac{5}{24} p^2 l^2}{S_1^2 - \frac{1}{4} p^2 l^2}.$$

Substituting for S_1 successively T and t, the values of a_1 and a_2 are obtained, and thence the total length of the rope.

In order to fix a rope for transmitting a given power, it is first hung loosely over the pulleys, and then strained up until the total length is equal to that already obtained by calculation. The end is then cut off, allowing a length of about 30 feet for splicing. A new rope lengthens at first under strain, and after some time requires to be taken down and shortened.

To determine the proper section of the rope, the strains to which it is subjected must be considered. These are (1) that due to tension; (2) that due to flexure. Let i be the number of strands in the rope, δ the diameter of a strand: then the maximum strain due to tension is given by

$$S = \frac{T}{\frac{\pi}{4} \delta^2 i}.$$

To find the strain due to flexure, consider what will happen if a wire of diameter δ is coiled upon a pulley of radius R. The fibres at the centre of the wire will retain their original length, those at the outside will be lengthened, and those at the inside shortened by a distance which, relatively to the length, is equal to

$$\frac{\frac{\delta}{2}}{R + \frac{\delta}{2}},$$

or, as it may be written,

$$\frac{\delta}{2\,R},$$

δ being always small. Hence, if E be the modulus of elasticity of the wire, the maximum strain due to flexure or Z $= E\,\frac{\delta}{2\,R}$. In the case of a rope made up of a bundle of strands the strain may be taken as the same upon each strand; and hence the maximum strain per unit of area on such a rope will be

$$S + Z = \frac{T}{\frac{\pi}{4}\,\delta^2\,i} + E\,\frac{\delta}{2\,R}.$$

The point at which this strain is found will of course be the extremity of the driving span, as it is here that the tension is greatest. The diameter of the strands and the working strain per unit of area being fixed, and the tension T approximately determined, it is clear that the above equation will give the number of strands, and thence the section and weight per lineal foot of the rope.

When in practice it is desired to find the tension, weight, and sag of a rope for transmitting a certain power, the resistances of the system are generally neglected, and approximate values assumed for the constants involved.

In some cases, and especially in order to ascertain the proportion of effective power transmitted, it is desirable to include the passive resistances. To simplify matters, the forces P and Q are then assumed to act at arms equal to the radii of the pulleys, which radii are themselves supposed equal, the shafts of course being equal also. On these assumptions the equations of equilibrium become

$$P + t - T\left(1 + \frac{s\,\Delta^2}{R}\right) - f_1\,\frac{\rho}{R}\,F = O;$$

$$T - t\left(1 + \frac{s\,\Delta^2}{R}\right) - Q - f_1\,\frac{\rho}{R}\,F^1 = O;$$

$$\frac{T}{t} = \mu\,\kappa.$$

Owing to the way in which P and Q enter into the expressions for F and F^1, these equations can only be solved approximately. Two methods of doing this are given.

Where the distance is great, several ropes in succession are employed, the driving pulley of each being mounted on the same shaft as the following pulley of the rope before it. In this case the equations for the first rope will be the same as those last given, except that Q, the resistance, will be the difference of the leading and trailing tensions on the second rope: for the second rope this

difference of tensions will represent the power and the corresponding difference for the third rope will represent the resistance, and so on to the last rope. These equations can be solved successively by the same approximate methods as before.

It often happens that at certain of these intermediate stations a portion of the power is taken off for use by a belt and pulley mounted on the same shaft. If this portion is considerable, the succeeding rope may be of smaller section and working on smaller pulleys. Equations of similar character to the above enable the tensions of this rope to be found when the amount of the power taken off is known.

The efficiency of the system, or the proportion of the net power transmitted to the gross power applied, is given by the ratio $\frac{Q}{P}$. To obtain an idea of the value of this ratio in ordinary cases the equations last given are simplified as far as possible by taking approximate values for F and F^1, neglecting the weight of the pulleys, and assuming that the tensions T and t are parallel. Taking the best experimental values for the constants involved, it appears that the loss in transmission for a single rope will not exceed about 6 per cent. Where there are several ropes in succession, the proportion of efficiency will be approximately represented by

$$\left(\frac{Q}{P}\right)^{\frac{m+2}{2}},$$

m being the number of intermediate stations.

Hitherto the transmission has been supposed to be in a horizontal line. The case is next considered in which one pulley is on higher ground than the other. Let H represent this difference in level, l the horizontal distance between the pulleys, S_o the tension at the point (real or imaginary) where the rope is horizontal, n the tangent of the angle which the rope makes with the horizontal at the point where it leaves the lower pulley. Then if the ratio $\frac{H}{l}$ be small, the curve may still be considered as a parabola, whose equation, referred to the lower point as origin, is

$$y = \frac{p x^2}{2 S_o} + n x.$$

Since when $x = l, y = H$, then

$$H = \frac{p l^2}{2 S_o} + n l;$$

hence the equation to the curve may be written

$$y = \frac{H - n l}{l^2} x^2 + n x.$$

The curve cuts the axis of x again at the point

$$x_o = - \frac{n l^2}{H - n l};$$

hence, if n be negative this point (and therefore the vertex of the parabola) is within the course of the rope; but if n be positive it is outside it.

The tension at any point is equal to

$$\sqrt{S_o^2 + p^2 \left(x - \frac{1}{2} x_o\right)^2}.$$

Where the ratio $\frac{p}{S_o}$ is small, the tension at any point is approximately equal to the weight of a length of rope equal to the height of the point above a horizontal line drawn at a distance $\frac{S_o}{p}$ below the vertex of the parabola. This property (analogous to that which is rigidly true in the catenary) enables the tension to be readily found by a diagram.

Where $\frac{H}{l}$ is not sufficiently small, it is necessary to consider the catenary which is the actual form of the curve. The solution then becomes necessarily tentative; but a mode of abridging the labour of the trials, and thus obtaining an approximate result, is given in the Paper.

The equations of equilibrium of the driving pulley will be the same for an inclined as for a horizontal span. Those for the following pulley (which will generally be at the higher level, the power being brought up from the water to higher ground) are also similar in form, but the tensions will no longer be the same as at the other end of the span. The tensions at the lower point and the difference of level being known, those at the upper point can be calculated according to the methods just given. Here, however, a difficulty presents itself. In order that the motion may be uniform, the difference of the tensions at the lower and upper ends (corresponding to the Power and Resistance respectively) must always be equal. But as the tensions at the upper point depend on those at the lower, and on the other circumstances of the case, it does not follow that this condition will hold; and in point of fact it appears that it can never be accurately true. Where, however, the inclination is small and the curve does not differ sensibly from a parabola, the condition holds with sufficient exactness, as each of the differences is appproximately equal to p H. But when the inclination is steep, the condition will not hold, and the motion will be irregular and oscillatory. For this reason steep inclinations are always to be avoided in wire-rope transmission.

To obtain the tensions required the proper length must be given to the rope; and this must be found, as in the case of horizontal

transmission, by calculation from the form of the curve. This calculation is simple, whether the parabola or catenary be assumed as the form of the curve.

Since the tension at the higher point is the greatest, it is on this that the section, and therefore the weight of the rope, must depend. But this tension itself depends upon the weight of the rope. It is therefore necessary to assume a section for the rope in the first place, and afterwards to ascertain by calculation whether it is sufficient to support the resulting tension.

The greatest length that may be given to a span is not easy to determine, but is not less than 200 yards. For this distance no intermediate supports are necessary, but they are often required to prevent the sag of the rope from bringing it to the ground. They consist of posts, each carrying two pulleys, one above the other. Of these, that which supports the driving span should be as large as the end pulleys; but that which supports the following span may be smaller, as the tension is less.

The main pulleys are generally of considerable size—at Schaffhausen they are 14·1 feet in diameter; at Bellegarde, 17·4 feet. Their rims are hollowed into a V shape, the bottom of the V being lined with wood, leather, gutta-percha, &c., to give the requisite adhesion. In some cases two parallel ropes on the same shaft are employed, each of sufficient strength to transmit the whole power in case of the other giving way. Should their pulleys, by wear or otherwise, come to be of different diameters, any slipping of the ropes may be avoided by a neat arrangement of loose bevel gear, invented by M. Ziegler, of Winterthur.

Finally, M. Achard points out that transmission of power by wire ropes has a special advantage where the power has to be distributed amongst various lessees; for the power to be given out by the leading-off rope at any station depends on its tension, which should be under the control of the proprietor; and any attempt on the part of a lessee to take more than his allotted share would only result in the slipping of his rope.

W. B. R.

On the Screw-Propeller. By Gisbert Kapp.

(Civilingenieur, vol. xx., cols. 403–442.)

The action of every propeller consists in moving the water within its reach with a certain velocity backwards, and in transmitting the resistance of the latter as motive power (thrust) to the ship. Calling M the mass, w the velocity of water passing per second through the disc of a screw-propeller, the thrust is

$$T = M w.$$

The work lost in the water flowing astern is

$$L = M\frac{w^2}{2} = T\frac{w}{2}.$$

To produce a certain thrust with a small amount of loss, w ought to be small and M large. This requires a propeller of such construction that it moves much water with little velocity. (Figs. 1 and 2.)

Fig. 1.

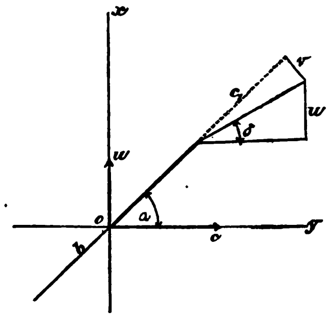
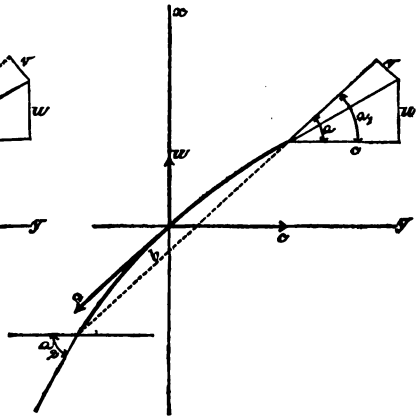


Fig. 2.



Let U be the velocity of the ship, u the velocity of the screw, r the distance of an elementary strip ($b \times d\,r$) from the axle, c its circumferential and ω its angular velocity, α its mean angle of pitch, α_1 this angle at the front edge, α_2 this angle at the back edge, c_1 the velocity of water alongside, v its velocity towards the strip, j its density, $d\,\mathrm{X}$ the thrust, $d\,\mathrm{Y}$ the rotary resistance of the strip, and μ a co-efficient referring to the resistance of the water; then

$$v = c \sin \alpha - u \cos \alpha.$$

For a screw with constant pitch (Fig. 1), the equations will be

$$\begin{cases} d\,\mathrm{X} = \mu \dfrac{j}{g} b\, d\,r\, v^2 \cos \alpha \\ d\,\mathrm{Y} = \mu \dfrac{j}{g} b\, d\,r\, v^2 \sin \alpha. \end{cases}$$

If the screw has an increasing pitch (Fig. 2), and if the angle of the front edge is so chosen that the water enters without shock, the thrust and the rotary resistance are 1·66 time as great as in the case of the constant pitch.

The angles have then to answer the conditions—

$$= tg\, \alpha_1 = \frac{u}{c}$$

$$= \alpha = \frac{\alpha_1 + \alpha_2}{2}.$$

The latter equation requires the developed leading line of the screw to be part of a circle.

To get the duty, the work done is divided by the force employed—

$$\eta = \frac{u\,d\,X}{c\,d\,Y} = \frac{u}{c\,tg\,\alpha}$$

$$\eta = \frac{\text{actual way of screw}}{\text{theoretical way of screw}}.$$

Calling the slip G, it stands

$$\eta = 1 - G.$$

In order to get η constant on the whole surface of the blades, these must be formed according to the condition $c\,tg\,\alpha =$ constant. This requires an ordinary straight screw whose mean pitch is

$$h = 2\,\pi\,r\,tg\,\alpha.$$

Since the pitch of entrance and the mean pitch are constant, the pitch of outlet has slightly to increase from the circumference towards the centre on account of the condition $\alpha_2 = 2\,\alpha - \alpha_1$. Every ship in motion draws water behind her, so that $u < U$; let ξ be a co-efficient acocunting for the draught of dead water, then

$$u = (1 - \xi)\,U.$$

The slip usually determined at trials has reference to U instead of to u, and may therefore be called the apparent slip G′. It is always less than the real slip G.

$$G = G'(1 - \xi) + \xi.$$

A strong draught of dead water cannot negative the apparent slip; thus if G′ were nil, G would be equal to ξ. The ship would communicate to the surrounding water a velocity G U, which would be annihilated by the screw. By this process, even in the most favourable case, viz., when all the water moved by the ship is afterwards consumed by the screw, only a state of equilibrium, but no surplus of thrust to keep the vessel in motion, can be expected. Besides the loss of work through the slip, there is a loss due to the friction of the blades and to the resistance of the leading edge. A small pitch and large blades reduce it, but increase the other resistances, and *vice versâ*; so that the total duty depends on the more or less favourable division of the different losses. It is impossible to calculate the best ratio between slip and friction; the only way to find it is by dynamometrical experiments made at various speeds and various resistances of the ship.

The total duty as a function of the slip can then be represented by a curve, to the highest point of which the most favourable slip belongs.

The resistance produced by friction is the more perceptible the sharper the angle is under which the water enters. It will there-

fore be advantageous to make the blades wide where this angle is a maximum; this is when $r = \frac{1}{\omega}\sqrt{u\,c\,tg\,a}$. In the axle, and at an infinite distance from it, this angle is nil, and so is the width of the blades. This leads to the shape of the Griffiths propeller.

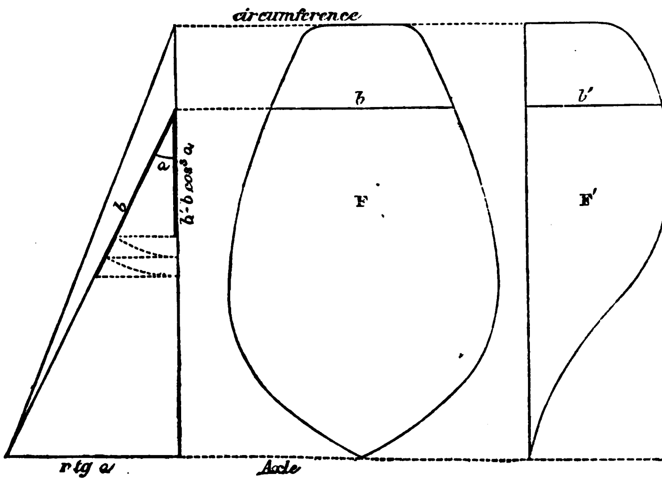
To obtain the thrust of a screw of m blades it is necessary to find the integral, $\quad T = m \int_i^a d\,X,$

between the limits of the inside and outside radii,

$$T = m\,\mu\,\frac{j}{g}\,\frac{G^2 u^2}{\eta^2}\int_i^a b\cos^3 a\,d\,r;$$

$\int_i^a b\cos^3 a\,d\,r$ represents a surface, F′, which can be obtained out of the surface of the blade F by making a threefold projection of it (Fig. 3).

Fig. 3.



Calling $\frac{G'(1-\xi)+\xi}{G} = \lambda$, then $T = m\,\mu\,\frac{j}{g}\,U^2\lambda^2 F'$.

Let A be the immersed midship section, and ζ the co-efficient of ship resistance, then

$$\zeta\,\frac{j}{g}\,A\,U^2 = m\,\mu\,\frac{j}{g}\,U^2\lambda^2 F';$$

$$\frac{\zeta}{\mu} = \lambda^2\,\frac{m\,F'}{A}.$$

The smaller the value of ζ, and the larger that of μ, the better is the ratio between the resistance and the power. The fraction $\frac{\zeta}{\mu}$

therefore gives a means to estimate the quality of the construction of vessel and propeller, and may be called the ratio of efficiency, which can be determined by ordinary trials.

Out of eight trials made with Austrian ships, the ratio of efficiency was between the limits ·0023 and ·0039.

To make the foregoing theory suitable for practical calculations, it is necessary to determine the co-efficients ξ, ζ, and μ for various kinds of vessels and screws. This must be done by experiment in the following way:—

Make two trials with the vessel; one at low, the other at high speed; notice the number of revolutions n_1 and n_2, the speeds of the vessel U_1 and U_2, the apparent slips G'_1 and G'_2; measure the thrusts T_1 and T_2; then

$$\xi = 1 - h \left\{ \frac{n_1 - n_2 \sqrt{\dfrac{T_1}{T_2}}}{U_1 - U_2 \sqrt{\dfrac{T_1}{T_2}}} \right\};$$

$$1 - G' = \eta';$$

$$\lambda = \frac{1 - \eta'(1 - \xi)}{\eta'};$$

$$\zeta_1 = \frac{g\,T_1}{j\,A\,U_1^2}; \quad \zeta_2 = \frac{g\,T_2}{j\,A\,U_2^2};$$

$$\mu = \frac{g\,T}{m\,j\,\lambda^2\,U^2\,F'}.$$

G. K.

Report on a Test Trial of a Swain Turbine Water-wheel, at Boott Cotton Mill, U.S. By JAMES B. FRANCIS.

(Journal of the Franklin Institute, April 1875, pp. 249–255.)

The wheel which was tested is 72 inches in diameter at the outer edges of the buckets, and 23·35 inches in depth from the under side of the crown to the lower edge of the band. It has twenty-five buckets of bronze, which were formed between dies in a press; and the crown plate and the lower band of iron are cast upon them. The gate has twenty-four guides, three of which are of cast iron, the remaining twenty-one guides being of bronze 0·23 inch thick, and 18·94 inches long. The guides are sharpened at each end to a thickness of 0·04 inch, bevelled on each side for a length of 1 inch, and so set as to form an angle of 14° with the tangent to the wheel passing through their inner edges. The inner edges are $1\frac{5}{8}$ inch distant, radially, from the outer edges of the buckets. The maximum opening of the speed-gate was 13·08 inches. The discharging

edge of each bucket lies in a vertical plane, passing through the axis of the wheel and parallel to it for a distance of 8½ inches below the crown. Below this limit the edge of the bucket is continued in the form of a quadrant, of which the radius is equal to one-fifth of the diameter of the wheel, struck from a centre in the outer circumference of the wheel. Each bucket thus forms with the surface of the adjoining bucket an outlet which combines an inward and a downward discharge. The total area of the twenty-five outlets was 9·558 square feet, and the mean shortest distance from the inner edge of each of the twenty-four guides to the side of the adjacent guide was 4·53 inches. The total area of inlet in the speed-gate was 9·88 square feet.

In August 1874, one hundred and forty-six experiments were made with this wheel, the results of which are fully recorded in a table. These results were plotted, and a series of mean curves drawn for the several heights of gate, from which another table is constructed, showing the co-efficients of useful effect for various heights of speed-gate of from 2 inches to 13·08 inches, and circumferential velocities of wheel ranging from 60 per cent. to 80 per cent. of the respective velocities due to the heads acting on the wheel. The annexed abstract from the second table shows the co-efficients for the extreme ratios of velocity just indicated, and the maximum co-efficient, with the relative velocity-ratio, for each height of speed-gate:—

SWAIN TURBINE WATER-WHEEL.

CO-EFFICIENTS of USEFUL EFFECT for SEVERAL HEIGHTS of SPEED-GATE, and VELOCITY-RATIOS (that is, the Ratio of the Circumferential Velocity of the Wheel to that due to the head acting on the Wheel.)

Height of Opening of Speed-gate.	Co-efficient for Velocity-Ratio, 60 per cent.	Co-efficient for Velocity-Ratio, 80 per cent.	Maximum Co-efficient with its relative Velocity-Ratio.	
			Co-efficient.	Velocity Ratio.
Inches.				Per cent.
13·08 full gate	·765	·831	·835	76·5
12	·775	·831	·839	76·0
11	·775	·815	·833	73·5
10	·782	·809	·834	72·5
9	·779	·800	·828	72·0
8	·771	·783	·807	71·0
7	·764	·757	·790	69·5
6	·742	·722	·761	67·5
5	·708	·693	·722	66·5
4	·654	·633	·699	66·5
3	·576	·545	·586	66·0
2	·474	·375	·474	60·0

It may be noted that from 9-inch gate to 13·08-inch gate, or, say, from about two-thirds gate to full gate, the maximum co-efficient of useful effect varies from 0·828 to 0·839, or about

1 per cent., the corresponding velocity-ratios being 72·0 for 9-inch gate, and 76·5 for full gate.

At half gate the maximum co-efficient is about 0·780, and velocity-ratio 68·0 per cent. At quarter gate the maximum co-efficient is about 0·610, and the velocity-ratio 66 per cent.

D. K. C.

Machine for Testing Metals by Tension and Flexure.

(Portefeuille Economique des Machines, March 1875, pp. 33–37, 3 pl.)

This apparatus for testing metals, constructed by the Compagnie des Forges et Chantiers de la Méditerranée at Marseilles, consists of a testing machine proper, and of an hydraulic pump for supplying the requisite pressure. The machine stands on a bed plate resting on a solid stone foundation, and its principal parts are an upright cylinder of 18·8 inches internal diameter, supported by four T-shaped upright castings united at various heights by bands cast in the solid with the uprights. The top of the cylinder being uncovered, admits of a free up and down movement of the ram, which is 2 feet deep, and is hollow. The piston rod, 5·3 inches in diameter, passes through the bottom of the cylinder, and both it and the piston are kept tight by ordinary hydraulic cup leathers.

The lower end of the piston rod terminates in a jaw, to which is fastened by means of a cross-pin the upper end of the specimen to be tested. At the bottom of the upright casting, and directly in the axis of motion of the piston, is the extremity of the short arm of a lever, to which the lower end of the specimen is attached. The arms of this lever are in the proportion of 1 to 10, the fulcrum on which it moves is firmly bolted to the bed plate of the machine. Between this lever and the weight are two other levers, each having ends of a proportion of 10 to 1, so that the multiplication of leverage between the specimen and the weight is 1,000 to 1. The third lever is graduated, and besides the principal load at its extremity, a small weight can be placed accurately and without disturbance at any point on the lever by means of a screw and hand wheel.

There is a set of three pumps, which must be worked with care, and at a rate dependent upon the indications of the specimen; but, as they can be managed by one man, the whole apparatus only requires the attention of two persons. Since by this machine the strain can be gradually increased without sudden and injurious jerks, the exact strength of any specimen can be ascertained with the greatest nicety.

For plates of iron or steel the test bars of the Marine Department in France are cut out of the plates to be proved, and are rectangular, having for a length of 7·8 inches a section of 1·18 inch by the thickness of the plate, whatever that thickness may be. The total length of the specimen between the points of suspension is 15·72 inches,

and the width at those points where the holes for the attaching pins pass through is 3·9 inches. Care is taken to use large radii where the specimen changes its width, so as to avoid abrupt alteration of form.

For common iron plates the initial strain is 15·8 tons per square inch, under which the elongation must not exceed 2·5 per cent. after a lapse of five minutes. At the moment of rupture the strain should not be less than 17·7 tons per square inch, nor the elongation less than 3·5 per cent.

For ordinary iron plates the initial strain is 17·8 tons per square inch, under which, after a lapse of five minutes, the elongation should not exceed 4 per cent. At the moment of rupture the strain should not be less than 20 tons per square inch, nor the elongation less than 5 per cent. For fine plates 18·4 tons per square inch is the initial strain, with an elongation of 5·5 per cent., while the breaking strain is 20·2 tons per square inch, and the corresponding elongation 7 per cent. For superior plates the strains are nearly 19 and 22·2 tons per square inch, and the respective elongations 7·5 and 10 per cent. The measurement for elongation is made by a pair of screw dividers, and does not merit special remark.

In testing cannon-tube steel for the Ordnance Department[1] the sample bars are made cylindrical instead of rectangular; their lengths vary, and when they are tempered in oil at a heat between a cherry red and the yellow exhibited by steel tools when being 'let down,' they must fulfil the following conditions:—The elongation must be gradual and progressive, and the elongation which precedes that due to the final extension just before rupture must be at least 2·5 per cent. at a minimum strain of 40 tons per square inch; whilst the permanent extension of the bar under a load of 18·4 tons per square inch must not exceed 0·015 per cent.

The test for deflection is made in a somewhat similar manner. To the end of the piston rod is fastened a beam about 5·5 feet long, and 11·8 inches deep at the points of suspension. The beam is pierced near the two extremities by numerous holes drilled at convenient distances, from two of which, equidistant from the axis of the piston rod, the specimen is suspended. Precisely in the centre between these points of suspension, and therefore in a line with the piston rod, the specimen is griped by a hook attached to the end of the lever as in the previously described experiments. The pumps are then set to work until the specimen is lifted, so as to be slightly retained by the centre hook, at which moment the lever should indicate 0. The test is then continued as for the tensile strains, and the deflection may be easily measured.

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[1] In the "Reports of Experiments on the Strength and other Properties of Metals for Cannon," published in Philadelphia and in London in 1856, a description is given (page 307, and plates 11 and 12) of the testing machine used by the Ordnance Department of the U.S. Army. One of the machines so described, and manufactured in America, has been for many years in use at the Royal Gun Factories at Woolwich.—SEC. INST. C.E.

The Spanish, Italian, and Brazilian Governments, and many private factories, are at present using this machine, the weight of which is 4·4 tons, and the price about £320.

H. T. M.

Clamond's Thermo-Pile. By M. du Moncel.

(Bulletin de la Société d'Encouragement, May 1875, pp. 234–241.)

This thermo-electric pile, which has been some time under the notice of electricians, is the subject of a report by Count du Moncel. The principle, though originally due to Seebeck, has been brought to its present perfection by Clamond. The active elements were originally iron, and the sulphide of lead, known as galena, which when properly arranged and heated, gives an energetic thermo-electric current; but M. Clamond had to abandon the galena in consequence of its high electrical resistance under the conditions necessary to a thermo-pile, and in the instrument as now constructed the iron is retained for the electro-positive element, while for the galena an alloy of zinc and antimony is substituted. Iron is preferred to copper, although the latter would give a higher electro-motive power, on account of its insensibility to the action of the alloy at high temperatures. The elements of iron and alloy are connected in sectors, in circular plates, arranged in thermo-electric series; each circular plate is insulated from those above and beneath it, and has its polar extremities united to a commutator, by the aid of which the several plates may be connected for 'quantity' or 'tension' as required. The pile is heated by gas, conducted through the centre of the circular plates by a tube of refractory clay pierced with holes on the cylindrical surface. As thus arranged, the pile yields an electric current, which will deposit electrolytically 20 grammes of copper per hour, with the consumption of 170 litres of gas, or at a cost of 10·8*d.* per pound of copper deposited.

P. H.

On a New Source of Magnetism. By M. D. Tommasi.

(Comptes-rendus de l'Académie des Sciences, April 19, 1875, p. 1007.)

When a current of steam, under a pressure of 5 or 6 atmospheres, is passed through a tube of copper of 2 or 3 millimètres diameter, rolled in a spiral round a cylinder of iron, the latter is magnetised to such a degree, that an iron needle placed at the distance of some centimètres from the steam magnet (*aimant-vapeur*) is strongly attracted, and remains magnetised as long as the current of steam passes through the copper tube.

E. B.

On the Resistance to the Passage of an Electrical Current at the Points of Contact of Metallic Conductors. By F. C. G. Müller.

(Poggendorff's Annalen der Physik und Chemie, No. 3, 1875, pp. 361–367.)

Some experiments on this subject are described, in which a chain of brass wire, consisting of fifteen links, was introduced into a voltaic circuit. The points of contact were cleaned by friction with a rouged string, and the chain could be weighted as desired. The resistances are given in arbitrary units. From measurements in which a zinc-carbon element and a Daniell's element were used as electromotors, the Author considers the resistance to the passage of the currents at the points of contact to be independent of quantity and electromotive force. In these experiments the chain was loaded with 100 grammes; with a load of 400 grammes the resistance was reduced to about $\frac{1}{14}$ of the former amount, and became inconsiderable. The resistance caused by the use of screw unions would be inappreciable, as by tightening the screw a pressure equal to several kilogrammes can be produced.

A considerable resistance may be introduced by the use of a Ruhmkorff's commutator; this, in one case, proceeded from the weakness of the contact springs, and from their being equal in strength; so that when vibration occurred, the cylinder found a fresh point of contact. It is recommended, therefore, to make the contact springs as strong as possible, and of unequal strength.

W. H. D.

Experiments on the Artificial Imitation of Native Permanent Platinum Magnets. By M. Daubrée.

(Comptes-rendus de l'Académie des Sciences, 1st March, 1875, pp. 526–532.)

The Author first refers to the discovery by Berzelius and von Kokscharow, that certain platinum ores form permanent magnets of greater strength than the magnetic oxides of iron: these ores contain 12 to 19 per cent. of iron, and the name of Eisenplatin was given to them in 1826 by Breithaupt. A sample was discovered to have three axes and six poles, by means of the figures produced on a layer of iron filings by the approach of the magnet, and also to be composed of various elements by the action of heat and acids upon it. A nugget was fused, part of the iron burnt away, and the residue was still magnetic but without polarity. Platinum was next fused, and very soft iron wire was added in the proportion of 1 of iron to 4 of platinum. On cooling the alloy was found to be a permanent magnet, which was broken in the endeavour to forge it into a bar, the same taking place with the native platinum magnets. Each portion was permanently magnetized, showing that the presence

of iron in proper proportion is sufficient to account for the polarity of platinum ore. A groove being cut in the crucible, a bar was obtained, which both acted on the magnetic needle, and had poles of contrary sign, two at each extremity; on analysis it was found to contain 16·87 per cent. of iron, and 83·05 of platinum. Alloys containing 99, 75, and 50 per cent. of iron were next formed, which, although magnetic, gave no traces of polarity. As the alloys first referred to became permanent magnets at once, the Author next observed the effect of the magnetic induction of the earth, by placing the groove of the crucible during fusion exactly in the plane of the magnetic meridian. After solidification, while still hot, the bar was set parallel to the dip, and became in every respect similar to the magnetic needle: on reversing it and heating it to a red heat, its poles were exactly reversed. These results are theoretically interesting—and perhaps also practically—where a great degree of permanency is desired either in magnets or magnetic needles.

E. B.

Remarks on Thomson's Electrometer. By K. A. Holmgren.

(Poggendorff's Annalen der Physik und Chemie, No. 4, 1875, pp. 630–643.)

Certain sources of error are pointed out in this Paper, in consequence of which the positive and negative poles of a galvanic battery may show a difference in tension when measured by a Thomson's electrometer. The electrometer employed seems to have been provided with two semicircular discs instead of quadrants.

There are three sources of error, in the same direction, and such that of two quantities of electricity of equal magnitude, but opposite sign, the electrometer makes that the smaller which has the same sign as the charge of its Leyden jar. Thus, the angular deviation u is given by the indicator charged with a quantity of electricity μ, the discs being charged with M and m quantities of electricity of opposite sign. The signs of the quantities M and m being changed, the indicator will make a deviation u_1 in the opposite direction. The Author shows that u must be $> u_1$ if M and μ have opposite signs; and, conversely, $u < u_1$ if they have similar signs.

Secondly, suppose the charge Z of the indicator = O, *i.e.*, that the Leyden jar has no charge; a body, the condition of whose electricity K is to be examined, is connected with the electrode of the collecting disc. The form of the conductor composed of the proof-plane, the collecting disc and its electrode, together with the reaction of the electricity induced in the earth-disc and indicator, will determine what amount of K shall enter the apparatus. The magnitude (s K) of this amount will, evidently, be independent of the sign of K. But let, while the body charged with K is still connected with the collecting disc, a charge of electricity be communicated

from without to the indicator: if this charge (Z) have the opposite sign to K, the magnitude s K will be increased to $(s + t)$ K by the reciprocal attraction of K and Z. Conversely, if Z and K have like signs, s K will be reduced to $(s - t^1)$ K, in consequence of the resulting repulsion. A greater angular deviation will therefore occur in the former than in the latter case.

Thirdly, by the continued influence of the electrified indicator, the upper parts of the insulators of both discs (as well as the discs themselves) are kept in an actively electrical condition; the electricity of the insulators must be of opposite sign to that of the indicator. Consequently, when a quantity of electricity is communicated to the collecting disc, it is introduced between two oppositely electrified bodies: the indicator and the insulator. In the case where this introduced electricity is attracted by that of the insulator (now become free by the binding of the electricity of the indicator), the indicator will experience diminished repulsion.

To give accurate mathematical expression to the influence of the different sources of error would be, the Author says, a very difficult problem. A number of experiments were made with the electrometer, and are cited to confirm the existence and direction of the sources of error above mentioned.

W. H. D.

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